Delaware Bay and Estuary
Assessment Report

WHOLE BASIN

August 2005

Delaware Department of Natural Resources and Environmental Control

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Acknowledgments

This report, compiled by the Department of Natural Resources and Environmental Control's Delaware Bay and Estuary Basin Whole Basin Management team, represents a comprehensive assessment of the Delaware portion of the Delaware Bay drainage basin. This effort, overseen under the leadership of Mark Biddle, environmental scientist with the Division of Water Resources, challenged scientists, engineers, planners, and managers from throughout the Department to merge all the available environmental data and information about this basin into a single, comprehensive document.

Individuals that participated in this multidisciplinary initiative are to be congratulated for the time and talents that they devoted to this effort. The members of the Delaware Estuary team include:

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INTRODUCTION

The *Whole Basin Management* approach, developed by the Department of Natural Resources and Environmental Control (the Department), focuses on protecting Delaware's environment by managing it in a comprehensive and coordinated fashion. Using major drainage basins as the chief management units, the Department is bringing together the expertise of all its divisions (Air and Waste Management, Fish and Wildlife, Parks and Recreation, Soil and Water Conservation, Water Resources, and Office of the Secretary) to assess, monitor, and protect the health of Delaware's environment.

The basis for developing this report comes from the Department's realization that virtually every activity that takes place in the environment impacts multiple resources or land-use activities. For example, pollutants improperly disposed of on the land surface can leach into ground water or be transported to streams and other surface waters during storms, thus potentially affecting public drinking-water supplies, habitat, aquatic life, and recreational fishing. Managing the complex and dynamic natural world we call "the environment" requires the Department to examine it from multiple perspectives and by the many resources that it contains.

1.1 DELAWARE'S DRAINAGE BASINS

The Department's Whole Basin Management approach aims at managing all the biological, chemical, and physical environments of geographic areas in Delaware. These geographic areas have been delineated on the basis of drainage patterns. As shown in *Figure 1.1-1*, four major drainage basins encompass the state: the Piedmont, Chesapeake

Figure 1.1-1
Delaware's Basins and Watersheds

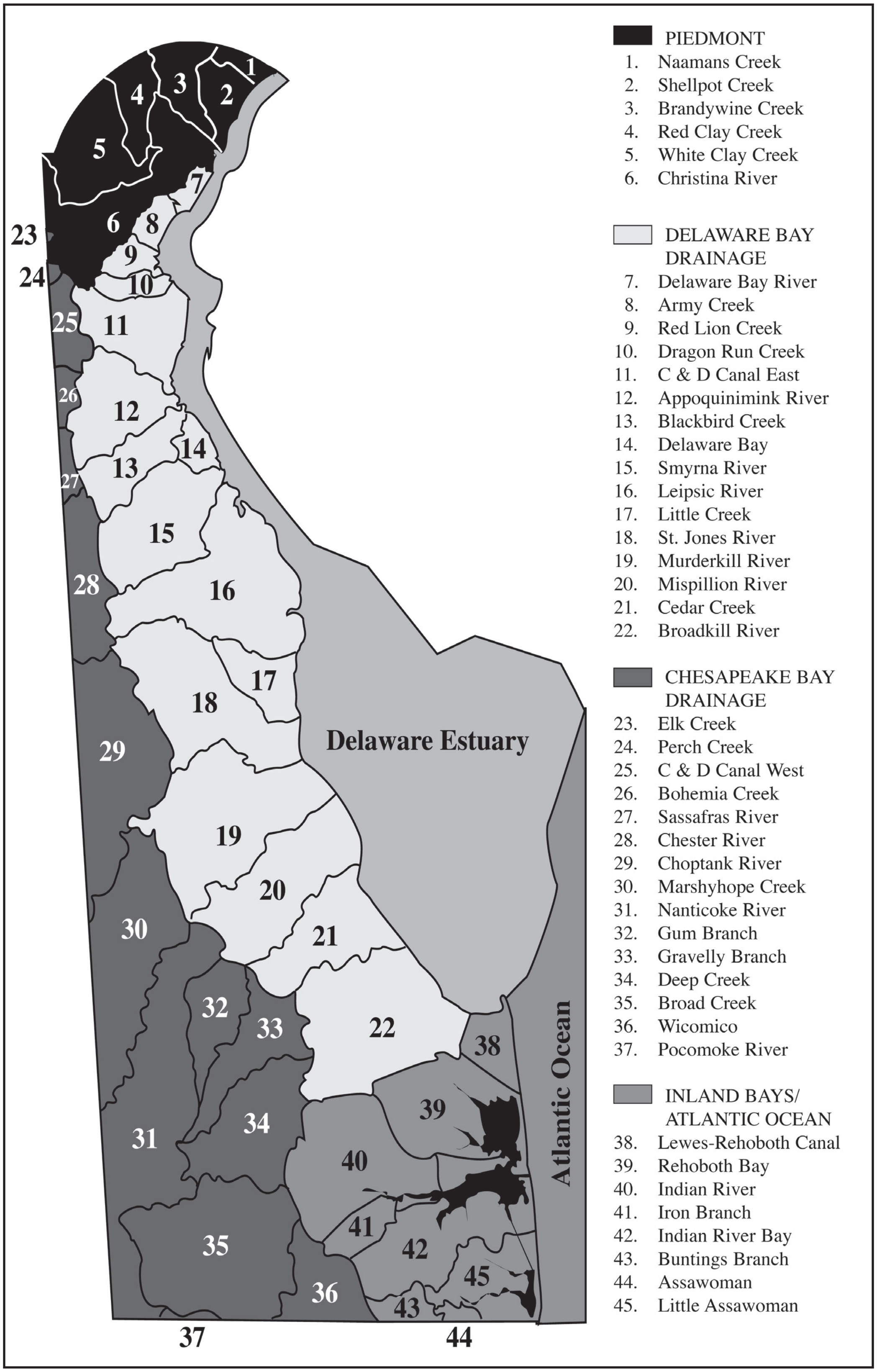


Table 1.1-1
Whole Basin Management Plan Progress

PHASE I: Planning (Months 0 – 4)

- Assemble team.
- Select team leader.
- Conduct training on consensus and team building.
- Develop outline for assessment.
- Develop Stakeholder Involvement Plan.

PHASE II: Assessment (Months 5 – 28)

- Inventory existing data and information.
- Assess status and identify trends.
- Identify specific issues of interest/concern.
- Make recommendations for focus and integration.
- Identify data gaps.
- Determine how issues and concerns are related to other media.
- Determine targeted indicators and how they should be monitored in the future.
- Determine if additional indicators need to be monitored in the future.

PHASE III: Intensive Problem Identification and Prioritization (Months 16 – 20)

- Incorporate existing white papers on key issues relevant to the Basin into the draft assessment and submit draft to external editor.

PHASE IV: Public Participation (Months 0 – 60)

- Perform agency and public review of draft assessment.
- Address public concerns and incorporate appropriate recommendations into assessment.

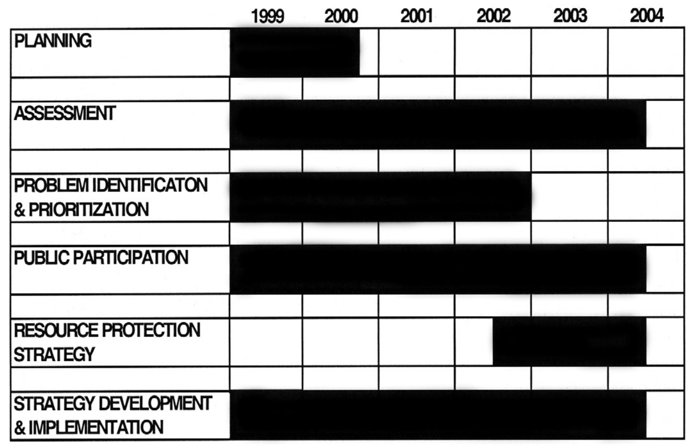
PHASE V: Resource Protection Strategies (Months 42 – 60)

- Develop pollution protection and watershed restoration strategies and management options.

PHASE VI: Strategy Development and Implementation (Months 0 – 60)

- Monitor, collect, analyze and/or organize (database development) information.
- Identify the roles and responsibilities of agencies involved in the priority issues.
- Modify Department monitoring programs to meet characterization needs (if necessary).
- Solicit public input on what should be done about the issue/problem.
- Select appropriate management options.
- Update Project Planning Document.

Figure 1.1-2
Delaware Bay & Estuary Basin Timeline



Bay, Inland Bays/Atlantic Ocean, and Delaware Bay & Estuary. Each basin consists of smaller management units, or sub-basins, known as watersheds. A watershed represents the area drained by a river, stream, or creek - in simplest terms, the area "shedding the water" to a given water body. There are 45 watersheds in Delaware.

Whole Basin Management utilizes a phased approach to effectively assess the health of a targeted basin, and to develop implementation plans to address environmental problems (refer to *Figure 1.1-2* and *Table 1.1-1*). The primary objectives of the process are to protect the environment, improve relations within and outside the Department, maximize wise resource use, and promote environmental education and stewardship. For more information, see the Whole Basin Management Framework Document, available at the Department's Office of the Secretary.

1.2 THE DELAWARE BAY & ESTUARY BASIN ASSESSMENT

The Delaware Bay & Estuary Basin is the fourth basin being assessed by the Department under Whole Basin Management. *Figure 1.2-1* shows Delaware's geographical location with respect to the Delaware Estuary. The Delaware Bay & Estuary Basin is located in eastern New Castle, Kent, and Sussex counties. The Basin is named for the area which it drains to - the Delaware Bay and Delaware Estuary. In Delaware, the land area that this basin drains is approximately 520,960 acres, or 814 square miles, and encompasses the following watersheds: Delaware River, Army, Creek, Red Lion Creek, Dragon Run Creek, Chesapeake & Delaware Canal, Appoquinimink River, Blackbird Creek, Delaware Bay, Smyrna River, Leipsic River, Little River, St. Jones River, Murderkill River, Mispillion

River, Cedar Creek, and Broadkill River (see *Map 1.2-1 Delaware Bay & Estuary Basin Watersheds*).

The Delaware Bay and Estuary Assessment Report, written by the Delaware Bay and Estuary Basin Team, representing every division in the Department, depicts the current state of the Basin, issues of concern, and assessment needs.

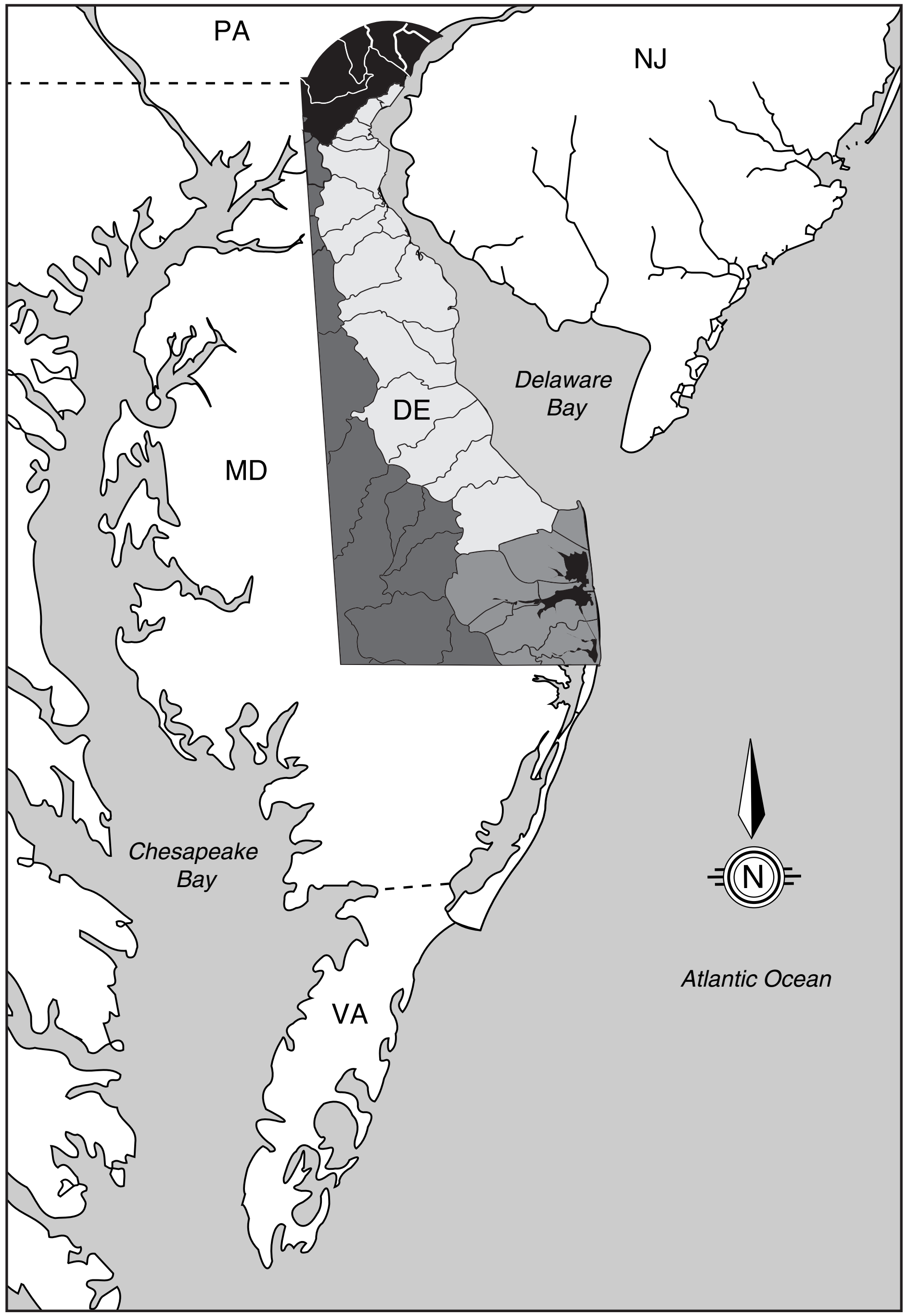
The assessment phase required gathering and assessing existing information for the Delaware Bay & Estuary from divisions within the Department as well as from outside agencies. Specific goals of the assessment phase are contained in *Table 1.1-1*. This assessment report should provide the "state of the environment" for the Delaware Bay & Estuary Basin. At a minimum, it should answer these basic, but essential questions:

- What do we know about the Delaware Bay & Estuary Basin?
- What don't we know?
- What do we need to know?

In preparing this assessment report, the Delaware Bay & Estuary Basin Team recognized that a great deal of attention has been given to the Delaware Bay & Estuary basin over the past several decades by agencies like the University of Delaware, Environmental Protection Agency, Delaware Estuary Program, and the Department. Numerous reports and management plans resulted from these efforts. The intent by the Delaware Bay & Estuary Team has been to utilize the existing data and information as they compiled this broad-based, multi-disciplinary assessment report.

This report identifies immediate actions that may be taken to improve the Delaware Bay & Estuary Basin's health, and makes recommendations for additional or enhanced monitoring of specific environmental indicators. Additionally, this report identifies data trends and gaps, areas of programmatic overlap, initiatives that may be integrated, areas requiring additional focus, environmental stressors, and other findings germane to promoting management of the ecosystem. This assessment provides recommendations that the basin team will focus on during the next phases of the Whole Basin process.

FIGURE 1.2-1
REGIONAL LOCATION OF THE DELAWARE BAY AND ESTUARY



ASSESSMENT

2.1 GEOLOGY, HYDROLOGY, AND SOILS

2.1.1 GEOLOGY

Almost all of Delaware's geological formations exist in the Delaware Bay and Estuary Basin. At least twenty-two major units have been mapped within the basin. Several of these units are exposed, or outcrop, at the ground surface (see *Map 2.1-1 Surficial Geology*). The remaining units lie immediately below the surficial units, or subcrop, at various locations within the Basin (see *Map 2.1-2 Subsurface Geology*). These units consistently dip to the southeast at a slope ranging from 15 feet to 90 feet per mile (see *Map 2.1-3 Geologic Cross-Section*). Older formations dip more steeply and subcrop beneath the younger formations (Talley, 1975).

To assist in understanding and visualizing the Basin's geology and hydrogeology, the following maps and tables are included:

Map 2.1-1 Surficial Geology shows the locations of the most recent geologic formations which are exposed at the ground surface.

Map 2.1-2 Subsurface Geology shows the locations of the subcropping or underlying geologic formations. This map illustrates what the geology of the Basin would look like if the surficial sediments were removed.

Map 2.1-3 Geologic Cross-Section shows a cross-section of the geology of the Basin. Refer to Map 2.1-2 to see the location of the A – A' transect. The cross-section represents what the geology of the Basin would look like if it were cut and viewed along the cut face. The cross-section shows all the geological units that occur within 1000' of the ground surface along a 77-mile path through the Basin. From this cross-section, aquifer thickness and depths to confining layers can be determined. Unconformities (periods of erosion or non-deposition) and faults are also indicated on the section. The locations of wells used to construct this cross-section are indicated using the Delaware Geological Survey well nomenclature.

Map 2.1-4 Hydrogeomorphic Regions shows the geographic areas determined by certain physical features that greatly influence water quality characteristics.

Map 2.1-5 Ground-Water Recharge Potential separates the Basin into areas of differing infiltration rates. Categorized from excellent to poor these regions show the relative ease with which rainwater, or any surface discharge, can enter the subsurface and thus the ground-water system.

C O N T E N T S

Geology, Hydrology and Soils

These figures will be referred to thoughout the Geology, Hydrology and Soils Section. Location references for the occurrence of geological formations and areas with notable hydrogeological characteristics will be denoted by town locations that are shown on the maps. Unless otherwise noted, towns will be used to denote the approximate northern and southern extent of the physical feature or topic which is being described. For example, stating "The Calvert Formation subcrop area occurs in the area between Townsend and Woodside" would specify the northern and southern extent of the Delaware Bay and Estuary Basin's Calvert Formation subcrop area respectively.

2.1.1.1 Physiographic Setting

The Delaware Bay and Estuary Basin lies entirely within the Atlantic Coastal Plain Physiographic Province. The coastal plain consists of a series of southeastward-thickening, unconsolidated sediments of Cretaceous through Holocene age deposited atop the Paleozoic and Precambrian crystalline "basement" rocks of the Appalachian Piedmont (*Table 2.1-1*). The Basin can be subdivided into two physiographic regions: the coastal lowland belt and the inland plain (Rima, Coskery and Anderson, 1964). These regions can be distinguished by their elevations. The coastal lowland belt contains extensive tidal marshes which lie between sea level and 5 feet above mean sea level; these marshes are separated by narrow necks of higher elevation (up to 20 feet above mean sea level). The inland plain consists of flat highlands (between 25 and 75 feet above mean sea level in the study area), cut by relatively narrow, steep stream valleys.

The coastal plain consists of a series of southeastward-thickening, unconsolidated sediments of Cretaceous through Holocene age deposited atop the Paleozoic and Precambrian crystalline "basement" rocks of the Appalachian Piedmont (*Table 2.1-1*).

The inland plain physiographic region lies to the west of the coastal lowlands, extending to the edge of the Basin. Generally the edge of the inland plain is marked by a rather steep rise from the coastal lowland to an elevation of 35 to 75 feet. The plain itself is relatively flat, sloping gently to the south. In general, it resembles a fluvial terrace. In some areas, there are small, undrained depressions called "Carolina Bays" (Rima, Coskery and Anderson, 1964). The elevation of the plain decreases from around 75 feet above sea level in New Castle County to around 35 feet in southern Kent County. The plain is interrupted by relatively steep valleys caused by headward erosion of the drainage streams. In some places tidal stretches of the streams reach all the way to the inland plain.

2.1.1.2 Hydrogeomorphic Regions

The U.S. Geological Survey (USGS) has characterized the Delmarva Peninsula into seven hydrogeomorphic regions (Hamilton et. al., 1991). These regions are defined by physical features including topography, surficial geology, hydrogeology, and soil conditions. Of the seven regions, the following four are found in the Delaware Bay and Estuary Basin: inner coastal plain, poorly-drained upland, well-drained upland, and beaches, tidal marshes, lagoons, and barrier islands (see *Map 2.1-4 Hydrogeomorphic Regions*).

The inner coastal plain is located in the northern portion of the Delaware Bay and Estuary Basin between Townsend and Town of New Castle and comprises about 15 percent of the basin's land area. The poorly drained upland comprises approximately 11 percent of the basin's land area and lies south of the inner coastal plain. The well-drained uplands are found throughout the majority of the basin from Smyrna to south of Milton and occupy approximately 57 percent of the basin's land area. The beaches, tidal marshes, lagoons, and barrier islands region occurs along the coastal portion of the Basin comprising approximately 17 percent of the land area.

Hydrogeomorphic classifications are useful for identifying water quality properties and patterns within a region. Each hydrogeomorphic region is characterized by specific water quality characteristics. Therefore, hydrogeomorphic regions can be used as a tool to help identify water quality patterns (Hamilton et. al., 1991). The USGS has related ground-water quality types and patterns to hydrogeomorphic regions.

2.1.1.3 Geologic History

Before the last ice age, ocean waters covered most of what is now Delaware. As the polar ice caps grew and continental glaciers advanced southward, most of the water to form these massive bodies of ice came from the ocean. Sea level withdrew from the land and dropped to its lowest level to a position near the edge of the present continental shelf about 400 feet lower than present-day sea level (Kennett, 1982). Since then, the polar ice caps have decreased in size and the continental glaciers have retreated, causing a corresponding rise in sea level to where we see it today.

Although Delaware is located south of the maximum extent of the last continental glacier, it is believed that the great weight of the massive continental glacier actually depressed the land it overrode. A corresponding marginal bulge formed in the area of present-day Delaware. As the glaciers retreated, the earth's surface rebounded upward in areas to the north and the marginal bulge previously formed in the area of Delaware subsided, causing a relative rise in sea level (Kraft and others, 1976).

TABLE 2.1-1 GEOLOGIC AND HYDROLOGIC UNITS OF THE DELAWARE COASTAL PLAIN

Age	Geologic Units	Hydrologic Units
HOLOCENE		
PLEISTOCENE	"Carolina Bay" deposits, upland bog deposits, Nanticoke deposits, Scotts Corners Formation, Lynch Heights Formation	Columbia/Unconfined/ Pleistocene aquifer – poor to excellent yield, minor confining beds
	Omar Formation	Confining unit over Columbia aquifer only in southeasternmost Sussex County – minor poor aquifer
	Staytonville unit, Columbia Formation	Columbia/Unconfined/ Pleistocene aquifer – poor to excellent yield, minor confining beds
PLIOCENE	Beaverdam Formation	
MIOCENE	Bethany formation	Interbedded confining units and Pocomoke aquifer – fair to excellent yield
	Manokin formation	Manokin aquifer – fair to excellent yield and confining beds
	St. Marys Formation	Confining beds – minor poor aquifer
	Choptank Formation	Interbedded unnamed aquifers; fair to good yields, and confining units; Milford aquifer – fair to good yield
	Calvert Formation	Confining beds Frederica aquifer – fair to good yield Confining beds Federalsburg aquifer – fair to good yield Confining beds Cheswold aquifer – fair to excellent yield Confining beds
OLIGOCENE	Glauconitic unit	
EOCENE	Glauconitic unit	
	Piney Point Formation	Aquifer poor to excellent yield, interbedded confining beds
	Shark River Formation	Confining beds
	Manasquan Formation	Rancocas aquifer – fair to good yield, interbedded confining units
PALEOCENE	Vincentown Formation	
	Hornerstown Formation	Confining beds
CRETACEOUS	Navesink Formation	
	Mount Laurel Formation	Aquifer – poor to good yield
	Marshalltown Formation	Confining bed
	Englishtown Formation	Aquifer – fair to good yield
	Merchantville Formation	Confining bed
	Magothy Formation	Aquifer – fair to good yield
	Potomac Formation	Potomac aquifers and confining units – fair to excellent yields
"BASEMENT" OF PRE-CRETACEOUS ROCKS		

Source: Adapted from Delaware Geological Survey, 1999

Compaction of coastal plain sediments can also contribute to sea level rise. As the Delaware, Susquehanna, and other rivers ran southeastward from the ancient Appalachian Mountains, they carried huge volumes of sediment which were deposited on the edge of the Piedmont to form the present Coastal Plain and continental shelf. Over time, these sediments began to compact, causing a drop in the elevation of the land surface. As the land sank, the ocean encroached onto the continental shelf causing it to flex downward and begin sinking. It is believed that the added weight of these sediments along with the weight of the ocean water has caused the Atlantic coast to subside about 9,800 feet over the last 150 million years (Thurman, 1981).

The current marine transgression began approximately 14,000 years ago when the polar ice caps began melting. The Delaware coastline at that time was approximately 80–100 miles east of its current location (Kraft and others, 1976). A rapid rise in sea level—about three inches per year—lasted until about 7,000 years ago, when sea level was about 33 feet below its present level. Since then sea level has risen at a slower rate until about 3,000 years ago when it reached its present level (Kennett, 1982).

As the ocean advanced across the continental shelf it flooded ancient river valleys and moved large masses of Pleistocene sediments in a landward direction, overtopping previous lagoons and marshes. Over time, Delaware's coastline, including both Delaware Bay and the Atlantic Ocean coastlines, began to evolve to its present-day configuration. The present coastline is moving landward and upward in response to longshore transport of sediments and storms. As sea level rises, waves attack the beach at higher elevations, which concentrates erosion on headland areas and works to straighten the coastline. At the same time, washover and blowing sand lead to the formation of dunes and a landward movement of the shoreline.

The landward and upward movements of the beach and dunes cause the shoreline to roll over itself over time. Evidence of this can be seen on the beach following a coastal storm when peat deposits and remnants of ancient pine forests that were landward of the shoreline are exposed on the present beach face. Radiocarbon dates taken from stumps and peat exposed in the surf zone of Dewey Beach have found that those stumps date to 320–420 years before the present. This indicates that the barrier island in this location has completely overtopped itself in only 400 years (Kraft and others, 1976).

Landward movement of the shoreline caused by sea level rise does not proceed evenly. Rather, it is episodic, such as at Fenwick Island where, between May 1977 and June 1979, the shoreline moved landward at an average rate of more than 30 feet per year. In general, Delaware's Atlantic coastline is moving landward at a rate of one to three feet per year. Even with our incomplete understanding, it is obvious that significant geologic changes can and do occur within a single human lifetime.

Pre-Miocene Depositional History

Deposition over at least the last 120 million years within the Basin has resulted in extremely thick sedimentary sequences comprised generally of alternating layers of unconsolidated sands, silts, and clays and admixtures of these textures.

The ground surface sediments of the Basin are ancient bay/estuarine bottom sediments which likely became dry after the deposition of the Omar Formation which occurred approximately 100,000 to 200,000 years ago when eustatic sea levels dropped (Groot and others, 1990). Further back in time, 50 to 60 million years ago, silty and clayey sediments in the Basin lying greater than 1,300 – 1,500 feet below ground surface, comprised part of the ocean floor on an ancestral Atlantic Continental Shelf. Changes in eustatic sea level are largely responsible for these varied depositional settings (e.g., continental shelf/estuarine settings) which largely influenced the lithology (sediment physical characteristics) of the geological formations found in the Delaware Bay and Estuary Basin. Currently, worldwide sea levels are rising and estuarine deposition is once again occurring. A brief formalized account of the geological history of the major geological formations (from oldest to youngest) comprising the Basin's stratigraphic column follows.

For all practical purposes, the depositional history of the Basin begins with the deposition of non-marine fluvial and flood plain deposits of the Potomac Formation (see *Map 2.1-3 Geologic Cross-Section*).

During the beginning of the Upper Cretaceous, a rise in eustatic sea levels resulted in a major marine transgression. This transgression resulted in the deposition of the marginal marine sands of the Magothy Formation which unconformably overlie the Potomac Formation. Marine conditions prevailed throughout the remainder of the Cretaceous Period and lasted approximately until about middle Eocene time (approximately 45 million years ago). This first major transgressive phase ended with the deposition of the silty glauconitic sands of the Piney Point Formation. From youngest to oldest, the intervening geological groups and formations between the Magothy and the Piney Point include the Matawan Group, the Mount Laurel Formation, the Navesink Formation, and the Rancocas Group. All of these formations are glauconitic, some are lignitic and fossiliferous (containing shell material and shark teeth, etc.), and most of them are fine-grained comprised chiefly of silts, clays, and fine sands (Pickett and Spolaric, 1971).

During the early Miocene (approximately 22 million years ago), the seas returned once again during a second major marine transgression. From oldest to youngest the following units were deposited uncomformably above the Piney Point: the Calvert Formation, Choptank Formation, and the St. Marys Formation. With the exception of the basal silt beds and basal sand beds of the Calvert, which were laid down in an outer continental shelf depositional setting and an inner shelf depositional setting respectively, the remaining aforementioned units were deposited under shallow marine to deltaic front environments (Pickett and Benson, 1983). Shallow marine deposition dominated until approximately the Middle to Late Miocene (approximately 15 million years ago) and ended with the deposition of the St. Marys Formation (Andres, 1986).

Deposition of Miocene-Pleistocene Sediments

The majority of the aforementioned geological formations lie too deep below the earth's surface to be mined and contain ground water too mineralized to be useful as a drinking water resource. With the possible exception of the Calvert and Choptank Formations, most of these units do not have significant ground-water resources; therefore, their geological history will not be discussed further.

According to Andres (1986), the St. Marys Formation was deposited during the Middle to Late Miocene under shoaling marine shelf (under a marine regression) and low energy conditions. Sea levels continued to drop during the rest of the late Miocene as the sands of the Manokin and then the Bethany Formations were deposited. The Manokin Formation represents a shallow marine to deltaic front deposit and is characterized lithologically as a lignitic gray to blue-gray and brown-gray clayey and silty sand at the base of the formation where it lies conformably on the St. Marys Formation. Deltaic deposition continued throughout the Basin during late Miocene time. As a result, the extremely heterogeneous Bethany Formation was deposited on top of the Manokin Formation. The Bethany Formation lies conformably upon the Manokin. During the early Pliocene (approximately 5 million years ago) sea levels continued to drop. Fluvial processes ensued with the deposition of the lower unit of the Beaverdam Formation which uncomformably overlies the Bethany Formation.

Subsurface/ Deep Units (Pre-Pliocene > 5 million years old)

The Atlantic Coastal Plain Sedimentary units found within Delaware Bay and Estuary Basin rest upon pre-Mesozoic crystalline basement rocks (rocks older than approximately 230 million years) (Sheridan and Grow, 1988). The oldest sedimentary unit found within the Delaware Bay and Estuary Basin is the lower Cretaceous Potomac Formation (refer to Table 2.1-3). This unit forms approximately the bottom third of the Atlantic coastal plain sedimentary wedge (Sheridan and Glow, 1988). These land-derived (terrigenous clastic) sediments accumulated under fluvial conditions approximately 100 million years ago (Pickett, 1976). The dominant textural types comprising the formation are silts and clays that were deposited within floodplains of ancient rivers. The sandy portions of this formation are river or stream channel deposits (Spolaric, 1967).

Potomac sediments were eroded during the early upper Cretaceous (approximately 90 to 100 million years ago) (Sheridan and Glow, 1988) as deep seas encroached upon the continents in response to a global sea level rise. The near shore coastal sands of the Magothy Formation were deposited on top of the Potomac and are the first marine sediments associated with this upper Cretaceous transgression (Pickett and Spolaric, 1971). Full marine conditions persisted until about the middle Eocene (about 45 million years ago) and ended with the deposition of the Piney Point Formation (Pickett, 1976).

Even though full marine environments persisted from the upper Cretaceous until the middle Eocene within the Basin, the seas that cover the area deepened and shallowed during the period which modified the types of sediments that were deposited (Johnston, 1973). Between the Magothy and the Piney Point formations, these transgressive/regressive seas led to the deposition of the following formations: Merchantville, Englishtown, Marshalltown, Mount Laurel, Hornerstown, Vincentown and Nanjemoy Formations (Pickett and Benson, 1977). Most of these formations represent inner to outer shelf deposits. Some of these formations, especially the Hornerstown and Vincentown formations, are highly glauconitic consisting of potassium, magnesium and iron silicate (i.e., green sand) and were primarily formed from biogenic processes (Pickett and Benson, 1983).

The Magothy Formation is a clean quartz sand, especially in upper part of the Basin. The Englishtown, Vincentown, and Piney Point formations are dominantly sandy while the Mount Laurel Formation is dominantly a silty sand. The Hornerstown Formation is variable in texture ranging from silt to clays with intervening silty-sand layers. The Pamunkey Formation is primarily fine-grained, composed chiefly of silt and clay (Pickett and Benson, 1977).

The seas retreated during the middle Eocene. From this time through about the Oligocene Epoch (until about 22 million years ago), there is no stratigraphic record of sedimentary deposits within the Basin. Erosional processes likely dominated during this period (Pickett, 1976).

During the Miocene Period (approximately 22 million years ago) the seas returned to the Basin and extended approximately to the Townsend area resulting in the deposition of the Chesapeake Group sediments (Pickett and Benson, 1983). These sediments include (from oldest to youngest) the Calvert, Choptank, St. Marys, Manokin, and Bethany Formations. Basal sandy silts of the Calvert formed on the outer continental shelf while near-shore marine conditions formed the dominant setting for the upper sandy members of the formation (Pickett and Benson, 1983). Deposition of the Choptank, St Marys, and Manokin formations occurred in a deltaic front to shallow marine setting while the Bethany represents primarily deltaic deposits.

The Calvert Formation is dominantly a sandy-silt with interlayer sand and shell beds. The Choptank is dominantly sandy with shell beds and thick fine-grained muddy beds. The St. Marys is dominantly clay but contains thin sandy beds. The Manokin is dominantly a sandy unit that coarsens upward from a silty-clayey sand to a fine-to-coarse sand. The Bethany Formation is dominantly a sandy-silt to silty-sand with intervening layers of fine to coarse sand (refer to *Table 2.1-1 Geologic Properties)*.

Recent Surficial Units (Post-Miocene < 5 million years old)

Younger primarily sandy surficial units blanket the underlying Chesapeake Group sediments and the older marine deposits. Deposition of these units occurred primarily under fluvial, deltaic, and estuarine environments. Fluvial deposition dominated throughout the upper portion of the Basin. With the exception of southern most portion of the Basin, the younger surficial units unconformably overlie older formations. The surficial deposits generally thicken to the south where in the southern portion of the Basin they attain a maximum thickness of approximately 230 feet thick (Andres, 1986). In the northern portion of the Basin these sediments are thinner (less than 10 feet thick in many areas) and may be entirely absent.

During the Pliocene (1.8 – 5 million years before present) deposition began in the southern portion of the Basin with the fluvial to deltaic deposits of the Beaverdam Formation (Andres and Ramsey, 1995). These sediments occur from around Milton to Georgetown. The Beaverdam was deposited under two main geological settings and is generally comprised of two varying lithological units. Deposition of the lower portion of the Beaverdam occurred under fluvial conditions while deposition of the upper portion occurred under deltaic conditions (Andres and Ramsey, 1995).

The seas once again transgressed during the Pliocene and resulted in the deposition of the upper (deltaic) unit of the Beaverdam. This portion of the formation is finer grained than the lower fluvial unit. Sediment textures range from a fine to medium sand to a clayey-silt (Andres and Ramsey, 1995). The Beaverdam ranges from approximately 50 feet to 100 feet over its range.

The Delaware Bay and Estuary Basin includes a small portion of the Staytonville unit. The Staytonville unit (a Pleistocene-aged deposit composed of interlayer strata of clayey and silty-sand and sandy-silt) rests upon the Columbia Formation in the Harrington area. The relationship of this unit to the underlying Columbia Formation is unclear. The unit may be an estuarine deposit. Thickness of this unit ranges from approximately 20 to 40 feet.

Climatic changes during the Pleistocene resulted in at least four interglacial periods. Pleistocene sea levels fluctuated in response to the glacial-interglacial cycles. Tremendous volumes of melt water shed from glaciers during interglacial periods caused sea levels to rise. As a result, major river valleys, such as the Delaware and Susquehanna River valleys, were flooded (Owens and Denny, 1979). Sea levels during the last interglacial period (the Sangomonian), which occurred approximately 300,000 to 360,000 years ago), resulted in sea levels approximately 25 feet higher than today. This transgression, or earlier similar transgressions during the Pleistocene, likely resulted in the deposition of the other estuarine surficial units within the Basin. This includes the upper portion of the Omar Formation. The upper Omar Formation is dominantly fine sand with interbedded silts, clays and shell beds (Ramsey and Schneck, 1990). Lithological changes within this unit occur rapidly both in the vertical and horizontal directions. Some of the silt beds may be highly organic (Ramsey and Schneck, 1990). The total thickness of the deposit is likely less than 25 feet in the Basin. This unit occurs in an extremely small area in the southeastern most portion of the Basin and comprises an almost negligible percentage of the surficial sediments within the Delaware Bay and Estuary Basin.

Current Geological Process

Holocene sediments are currently being deposited in the Basin (primarily fluvial, swamp, marsh, and bog deposits). Deposition of these units began approximately 10,000 years ago during the beginning of the present-day interglacial period (Andres and Ramsey, 1995). These surficial sediments comprise a relatively small percentage of the total sediment volume of the Basin and are found scattered throughout the Basin, generally along stream corridors and in wetland and bog environments.

2.1.1.4 Stratigraphy

Evaluating the stratigraphy, or relative vertical and lateral positions of sand, silt, and clay sediments in the Basin, is important for determining the location and extent of related resources such as ground water and mineral deposits. The stratigraphic units comprising the Coastal Plain deposits of the Basin range in age from the Cretaceous Potomac Formation (oldest) to unnamed Holocene deposits (most recent). The geologic record preserved in the Coastal Plain deposits of the Basin is very incomplete due to long intervals of non-deposition or erosion that occurred during periods of low sea level. Building on the initial efforts of Jordan (1962), the Delaware Geological Survey (DGS) has performed numerous investigations that have lead to a more-defined unit breakdown of the lithologic sequence found between these older and younger units. Detailed stratigraphic information is provided in the numerous references provided in the narrative below. *Table 2.1-1* provides a summary of the latest stratigraphic units recognized in the Basin by the DGS. The following paragraphs provide individual summaries of each of these recognized units.

Potomac Formation

The early Cretaceous Potomac Formation is a very thick, non-marine unit that represents the basal formation of the Coastal Plain sequence. The Potomac deposits comprise over 75 percent of the total sediment volume in the Basin. The formation is characterized by great lithologic variability both vertically and horizontally. The Potomac is distinguishable by its variegated white, yellow, gray, and red silts and clays interbedded with white, gray, and red-brown sands. While consisting mainly of fine-grained sand, silt and clay deposited in overbank and interfluvial environments, the Potomac also contains fluvial sands deposited in shifting stream channels. The thicker, more extensive, and cleaner sequences of these channel sands serve as major ground-water sources in the northern part of the Basin. The Potomac thickens to the southeast, but is not used as a water supply because of its depth.

Magothy Formation

The late Cretaceous Magothy Formation is a marginal marine deposit that represented the beginning of a major marine transgression. The Formation is comprised of clean sands with interbedded lignitic silts. The Magothy is laterally persistent throughout most of the Basin, but Spoljaric (1972) has identified areas near Delaware City where the Magothy is very thin or has been eroded around paleotopographic highs in the underlying Potomac Formation. Like the Potomac, the Magothy Formation thickens to the southeast.

Matawan Group

The late Cretaceous Matawan Group is comprised of the Merchantville, Englishtown, and Marshalltown formations, and represents a continuation of the marine transgressive sequence that began with the deposition of the underlying Magothy sediments. The Matawan appears to be the last unit present in the northern part of the Basin (above Delaware City) before encountering the Pleistocene Columbia Formation. More units appear in the stratigraphic interval between the Matawan and Columbia as one proceeds in the southeast (downdip) direction of sediment thickening.

The Merchantville Formation consists of dark gray to greenish-gray silty clays, coarse silts, and very fine sands. The Merchantville is laterally persistent throughout the Basin, although in parts of the north, channeling related to Columbia Formation sediment deposition has thinned or completely eroded the Merchantville. Also, while usually overlying the Magothy Formation, the Merchantville is found directly atop the upper clays of the Potomac Formation where the Magothy has been eroded (as described above). The Englishtown Formation lies between the underlying Merchantville and overlying Marshalltown formations. The lithology of the Englishtown is persistent from the Chesapeake and Delaware (C&D) Canal area to the Dover area - a fine to very fine-grained sand (Benson and Spoljaric (1996)). The relatively thin Marshalltown Formation is a greenish-gray to gray very fine sand and silt that is distinctive for its high glauconite content. The Merchantville and Marshalltown sediments represent transgressive marine shelf mud deposits, while the Englishtown Formation is thought to represent a regressive interlude of prograding shelf sands.

Mount Laurel Formation

The late Cretaceous Mount Laurel Formation is identified just north of the C&D Canal and is laterally persistent southward. The Mount Laurel is a calcareous, fossiliferous fine to medium sand in the north, but changes downdip to a predominant calcareous silt and clay in the Dover area.

Navesink Formation

The Navesink Formation is a relatively thin unit comprised of very glauconitic silty clays that are lithologically very distinguishable from the underlying Mount Laurel Formation. It is the uppermost Cretaceous unit in the Basin.

Rancocas Group

The early Tertiary (Paleocene) Rancocas Group consists of the Hornerstown and Vincentown Formations. This Group, along with the underlying late Cretaceous sediments, is thought to represent middle to outer marine shelf muds being deposited as part of a continued transgressive sequence. The relatively thin Hornerstown Formation is a greenish-gray to dark gray, calcareous, glauconitic silt. It is slightly less glauconitic than the underlying Navesink Formation. The visual similarity can cause difficulty in distinguishing the two units, but biostratigraphic data in support of geophysical log correlation have established the continuity of the two as separate stratigraphic units (Benson and Spoljaric, 1996). The Vincentown Formation is a glauconitic sand, part of which grades downdip into a calcareous fossiliferous silt identified by Benson and Spoljaric (1996) as the Deal Formation. However, the lower portion of the Vincentown persistently maintains its sandy lithology downdip, and this portion of the unit thereby maintains its identity to the south. Discussion of this relationship is presented below.

Deal Formation/Manasquan Formation/Shark River Formation

The early and middle Eocene Deal Formation is a thick, clayey, calcareous, shelly, glauconitic silt that has been interpreted by Benson and Spoljaric (1996) as the downdip, gradational equivalent of the late Paleocene Vincentown Formation (in part) and Eocene Manasquan and Shark River formations. Updip, the Deal can be subdivided into the clay-to-clayey silts of the Manasquan and the very clayey, glauconitic sands of the Shark River. Both of these formations pinch out as a facies change to the Deal Formation in the central part of the Basin. The Deal has previously been named the "Pamunkey" Formation. The Deal Formation grades both laterally and vertically downdip into the overlying sands of the Piney Point Formation.

Piney Point Formation

Deposition of the middle Eocene Piney Point sands represented the end of the major marine transgressive phase that started in the late Cretaceous. The Piney Point Formation is a bright green, fine to medium, glauconitic, shelly sand. Basal and updip portions of the Piney Point are more clayey as they grade into the silty to clayey Deal Formation. The Piney Point is also erosionally truncated updip north of Dover. The Piney Point is thickest in the Dover area, and represents a major ground water source for this part of the Basin.

Chesapeake Group

The Miocene Chesapeake Group is comprised of three formations. From oldest to youngest age, these formations are: the Calvert Formation, Choptank Formation, and St. Marys Formation. Calvert deposits represented the onset of a second major marine transgression in the region, with all three formations primarily representing inner shelf marine deposits. All three formations extend downdip from the middle to the lower portion of the Basin. Northward (updip), they are truncated by the erosional unconformity at the base of younger (Quaternary) deposits.

A reworked section of glauconitic sand at the top of the Paleocene Piney Point was previously thought to be Oligocene in age, but Benson and Spoljaric (1996) have since designated this downdip reworked material as the basal unit of sand and silt of the Calvert Formation. The early Miocene Calvert is primarily a sandy silt with sand and shell interbeds. Some of the sandy interbeds serve as important aquifers in the mid-Basin. These include the Cheswold, Federalsburg, and Frederica sands. The Calvert is over 400 feet thick in the middle and lower Basin, but thins rapidly to the north due to erosional truncation.

The middle to late Miocene Choptank Formation is typically sandier than the underlying Calvert Formation. A drill hole near Milford shows the contact between the two being very distinctive, consisting of a dark gray to brown, medium to coarse sand (Choptank) overlying a compact brown clay (Calvert) (Ramsey, 1997). Ramsey (1993) has divided the Choptank into a lower and upper unit, with the lower Choptank having better developed sands. Ramsey (1997) has designated one such developed sand body- an extensively used basal sand of the Choptank- as the Milford aquifer. The Choptank is over 140 feet thick in the "Milford" drill hole, but thins to a few feet in updip direction.

St. Marys Formation

The late Miocene St. Marys Formation consists of gray, fine to very fine sandy to clayey silt with thin sand beds that grades down onto or sharply overlies a gray, fine to medium sand. The St. Marys is roughly 60 feet thick in the Milford area, but thins to a few feet just a few miles north near Frederica. A minor sand body at the base of the St. Marys is used locally as a water source.

Manokin Formation

The Manokin Formation is characterized lithologically as a lignitic gray to blue-gray and brown-gray clayey and silty sand at the base of the formation where it lies conformably on the St. Marys Formation. The upper portion of the formation grades into a gray to yellow, orange to red orange, fine to coarse, quartz sand with common beds of gravelly sand (Andres and Ramsey, 1995; Ramsey and Schneck, 1990). Sandy portions of the formation form an important confined aquifer (the Manokin Aquifer) which occurs in most areas of the Basin. This aquifer is utilized most heavily along the coast where it supplies water to public wells (Talley and Andres, 1987). The formation generally thins to the north and west.

Bethany Formation

Ramsey and Schneck (1990) describe the Bethany as dominantly a bluish gray, gray, olive gray clay or silt with interbedded strata of fine to coarse sand, gravel and lignite. Andres (1987) has described the formation as being dominantly comprised of sand (fine to coarse) interbedded with silt, clay, and shell material. Fine-grained beds within the Bethany Formation are more continuous and numerous than the fine-grained strata found within the overlying Beaverdam Formation and the underlying Manokin Formation (Talley and Andres, 1987). This formation occurs at, or relatively close to, the ground surface and is extremely important in that it is often utilized as a source for water supplies.

Beaverdam Formation

The Beaverdam Formation (lower unit), which uncomformably overlies the Bethany Formation, is a light gray to yellow orange, medium to coarse sand, gravelly sand, and sandy gravel.

Columbia Formation

The early to middle Pleistocene Columbia Formation covers the most surface area in the Basin, and is of considerable economic importance as it provides significant quantities of ground water as well as sand and gravel. The Columbia is a fluvial deposit consisting of tan, brown, or reddish brown, medium to coarse sand with scattered thin beds of pebbles and gravel. Thin, discontinuous beds of silt and fine sand are also present. The Columbia is marked by an erosional angular unconformity that truncates underlying Cretaceous and Tertiary strata. The thickness of the Columbia approaches 100 feet in some areas, but is highly variable owing to its irregular bottom contact caused by intensive channeling into the older deposits (Groot and Jordan, 1999). Additionally, along the eastern margin of the Basin, deposits of the overlying Delaware Bay Group truncate upper portions of the Columbia.

Delaware Bay Group

The middle to late Pleistocene Delaware Bay Group was named by Ramsey (1997) to identify the sand, silt, clay and organic-rich deposits found adjacent to the present Delaware Bay. These deposits represent estuarine, tidal marsh, as well as fresh-water marsh sediments. The Group lies unconformably above Cretaceous and lower Tertiary rocks, the Chesapeake Group, and the Columbia Formation, and extends for a distance of over 50 miles between the outcrop of the Columbia Formation and Holocene sediments marginal to Delaware Bay (Ramsey, 1997). The Group is divided into the Lynch Heights (older) and Scotts Corners (younger) formations which thicken towards the Delaware Bay.

The Lynch Heights Formation is a light yellowish and light reddish brown to gray, medium sand with discontinuous beds of silty sand and clayey silts. The Formation is up to 50 feet thick, thinning towards the west. The Scotts Corners Formation consists of light gray to brown to light yellowish brown, coarse to fine sand with discontinuous beds of clayey silt, coarse to very coarse sand, and pebble gravel. The unit has a maximum thickness of 25 feet.

Unnamed Holocene Sediments

The most recent sediments being deposited in the Basin are termed "Holocene," and represent fluvial, swamp, marsh and bog deposits. These surficial sediments comprise a relatively small percentage of the total sediment volume of the Basin, and are generally found along stream corridors, as shoreline and bay deposits, and in wetland and bog environments.

2.1.2 HYDROLOGY

Ground water is the sole source of drinking water in the areas within the Delaware Bay and Estuary Basin, and is supplied from both the unconfined, or water table, aquifer and several confined and semi-confined aquifers. An aquifer is a transmissive body of water-bearing sediments or rocks that is capable of yielding significant quantities of water. Within the basin there are several identified aquifers, or aquifer systems, which provide the vast majority of potable ground water. This does not include smaller, laterally-limited water-bearing strata, those with sufficient yield for smaller domestic potable uses only.

Based upon similar results from ground-water quality analysis, Hamilton et. al. (1991) surmised that many of the water-bearing units in the Delmarva area can be grouped together into informal hydrostratigraphic aquifer systems. In discussing the hydrogeology of the Delaware Bay and Estuary Basin, this format and nomenclature will be followed.

Precipitation represents the sole mechanism of recharge for the unconfined aquifer. According to Johnston (1976), Delaware receives an average 45 inches of annual rainfall, of which 40% infiltrates through the soil to reach the water table. The remaining 50% is either directly discharged to surface water bodies through overland flow, or through evapotranspiration. Recharge of the ground-water system can occur only in areas where permeable sediments enable the water to readily infiltrate, termed recharge areas. The Delaware Geological Survey has recently completed ground-water recharge potential maps for the Delaware Bay and Estuary Basin (Map 2.1-5 Ground-Water Recharge Potential).

Recharge of the deeper, semi-confined aquifers is accomplished predominantly in their subcrop areas through downward migration of water from the unconfined, water table aquifer. Outside the subcrop area, recharge can also be accomplished through migration of water through leaky confining beds and direct communication with other aquifers.

Ground water moves much slower than surface water, and follows specific flow paths as it moves through an aquifer. These flow paths vary in length depending on the thickness of the aquifer and the proximity to ground-water discharge areas where it discharges into surface water bodies. According to Hamilton et. al. (1991), ground-water flow paths in the unconfined aquifer are generally short, in the range of 100s of feet to less than a mile. Velocity of ground water is highly variable, and dependent upon the linearity or tortuosity of the flow path, hydraulic gradient, and aquifer characteristics such as permeability and sediment composition. Pumping ground-water wells supply an artificial variable which affect ground-water flow velocity. In general, without such artificial influences, ground-water flow velocities are slow, usually less than one foot per day.

Several measurements have been developed to describe how readily ground water can move through an aquifer, the two most common measurements (sometimes called aquifer characteristics) being specific capacity and transmissivity. Specific capacity is an expression of well productivity, obtained by dividing the rate of discharge of water from the well by the drawdown of the water level within the well. Transmissivity is defined as the rate at which water is transmitted through a unit width of an aquifer or confining bed under a unit hydraulic gradient. It is a function of properties of the liquid, aquifer properties, and thickness of the aquifer (Fetter, 1988). These parameters will be used in the following discussion of ground-water availability to describe and compare the quality of the various aquifers, and their potential capabilities.

2.1.2.1 Water-Bearing Units

Unconfined Aquifer

Within the Delaware Bay and Estuary Basin, the water-table, aquifer is contained within gravelly sands of the Columbia Formation in the northern portion of the basin, and the Beaverdam Formation in the southern portion of the basin below Milton. In all but the southernmost part of the basin south of Milford-Milton, the water-table aquifer is strictly unconfined. Near Milford and Milton, relatively thin clays, silts and peats belonging to the Lynch Heights and Scotts Corners Fms of the Delaware Bay Group act as leaky confining layers (Ramsey, 1997). In the area of Lewes and Cape Henlopen, the Omar Formation, consisting of a mixed lithology of silty sands with silt-clay interbeds, behaves similarly (Andres, et. al., 1990).

Thickness of the Columbia-Beaverdam Aquifer varies from tens of feet in much of New Castle County north of the C&D Canal, to up to 140 ft in Sussex County, with thicker channel sand deposits in sections of New Castle and Kent Counties. In addition, throughout much of the Delaware Bay and Estuary Basin, the Columbia and Beaverdam aquifers are in direct hydraulic connection with deeper, older sands, which act as a single hydrologic unit in the area of subcrop. The results are a series of thick, very productive aquifers, capable of yielding large quantities of water. This includes areas of Potomac, Rancocas, Cheswold, Frederica and Manokin subcrops (refer to proceeding sections). In such areas, yields exceeding 1,000 gallons per mimute (gpm) are not uncommon, particularly in the Columbia-Manokin aquifer. The unconfined aquifer is heavily utilized throughout the Delaware Bay and Estuary Basin for supplying water to domestic, public, irrigation and industrial wells in each of the three counties in Delaware. The water-table aquifer receives recharge from precipitation, and not only provides large quantities of water to wells, but also provides baseflow to streams, and an unquantified volume to the Delaware River itself.

A large body of data exists regarding the hydraulic characteristics of the water-table aquifer, and as expected, there is a direct correlation between aquifer characterization data and aquifer thickness. In general, transmissivity and specific capacity increase as one proceeds south, with the highest values in Sussex County. Results of several aquifer tests conducted in the unconfined Columbia Aquifer are reported by Johnston (1973). With an approximate saturated thickness of 42 feet, transmissivities of 3,100 ft^2/day and 4,500 ft^2/day were reported from Dover and Middletown, respectively. Further south in Houston, the value increased to 22,000 ft^2/day (saturated thickness of 86 feet), and 15,000 ft^2/day in Lewes (saturated thickness of 130 feet). In another Middletown pump test, Groot, et. al. (1983) reports a value of 1,650 ft^2/day. Spoljaric and Woodruff (1970) measured 5,300 ft^2/day in Middletown and 8,000 ft^2/day in Smyrna. In a compilation of hydrologic data from coastal Sussex County, Talley and Andres (1987) list transmissivity values from numerous wells in excess of 10,000 ft^2/day, with a maximum 17,250 ft^2/day in the Basin.

Specific capacities are high, but wide-ranging, as would be expected for unconfined conditions. Sundstrom and Pickett (1971) provide a range of 0.7 up to 50 gpm/ft in northern New Castle County from the Columbia-Potomac Aq. Johnston (1973) reports values in New Castle County with a low of 3.5 gpm/ft in Newark and 10 gpm/ft in New Castle, to 27 gpm/ft at Atlas Point, up to 48 gpm/ft in Delaware City. In Kent County, specific capacities were measured from two public well systems, with 30 and 54 gpm/ft in Smyrna, and 18 and 29 gpm/ft in Milford. Spoljaric and Woodruff (1970) report 3.5 gpm/ft in Middletown. Talley (1982) reports specific capacities of 9 to 80 gpm/ft in the Milford area, with yields in excess of 500 gpm common. Results from the Talley and Andres (1987) study show an average in excess of 25 gpm/ft in Sussex County, with numerous values in excess of 50 gpm/ft.

In summary, the water-table aquifer is undoubtedly the most productive aquifer in the Basin, with little to no volumetric constraints on its use at this time. It presently supplies much of the potable and public water needs for much of the state, and can continue to be developed, although with some caution in areas where salt-water intrusion may represent a concern.

Potomac Aquifer System

The thick layer of unconsolidated sediments of the Lower Cretaceous Potomac Formation unconformably overlies the crystalline basement. The predominant lithology within the Potomac Formation is a dense silty clay, variegated in color. There are, however, migrating or overlapping channel sand deposits within the formation that represent important aquifers which are utilized in the northern part of the basin for domestic, public and industrial purposes. Utilization of the Potomac aquifers has generally been limited to the northern part of the basin due to the availability of shallow ground water below the

C&D Canal (Bachman and Ferrari, 1995). Historically, two distinct water-bearing zones, the "Upper Potomac Aquifer" and the "Lower Potomac Aquifer" were recognized. Recent studies however, have identified that the configuration of these hydrologic zones consist of migrating and overlapping channel deposits rather than laterally-continuous, and distinct, sand bodies, in which there is some degree of interconnection (Jordan, 1983). As noted by Phillips (1987), the vertical and horizontal variability of sediment distribution in the Potomac Formation makes aquifer correlation very difficult. At times two (Upper and Lower Potomac Aquifers), or three (Upper, Middle and Lower), aquifers have been identified, some of which have been even further subdivided into upper and lower sands. Further complicating the picture are the numerous intervals where there is direct interconnection between the sandy intervals, as well as interfingering of the Potomac sands with the sands of the overlying Columbia Formation near the Delaware River. Distinction between the water-bearing zones becomes even more difficult in the area south of the C&D Canal (Woodruff, 1986). In this report, the three-aquifer format will be followed, in keeping with the study by the U.S. Geological Survey (Phillips, 1987).

Data from numerous drillers' logs and geophysical logs used by the U.S.G.S. indicate that the uppermost aquifer in the area between Red Lion Creek and the City of New Castle is the Upper Potomac Aquifer, which is generally considered confined throughout its extent (Phillips, 1987). However, field data generated from investigations at several Superfund sites in the vicinity of Army Creek and Llangollen Estates suggest that small areas of subcropping and even outcropping Potomac sands may exist in this area, with the sands exposed due to anthropogenic activities as well as natural erosion. Thickness of the aquifer is estimated at 20 feet in the Red Lion Creek area, thickening to 40 feet north of Llangollen, and can be mapped as a continuous sand body towards the west/southwest. The aquifer is not continuous to the east, beneath the Delaware River, however, where Pleistocene and Holocene erosion has removed the overlying confining clays entirely in addition to a large portion of the Upper Potomac sands. In this area, the aquifer is in direct hydraulic communication with the overlying Columbia Aquifer as well as Holocene river sediments. Between the City of New Castle wellfields, the aquifer has a reported thickness of 18-42 feet in west wellfield, but only 10 feet in the east wellfield (Phillips, 1987).

North of New Castle to the Delaware Memorial Bridge can be found the Middle Potomac Aquifer. From the bridge to the Fall Line, the Middle Potomac Aquifer pinches out, and the Lower Potomac Aquifer represents the uppermost Potomac sand body (Phillips, 1987). Less stratigraphic control is available regarding the geometry and thickness of the Middle Potomac Aquifer than there is for the Upper Potomac Aquifer. It has been encountered in wells in the City of New Castle east wellfield, and is also utilized by Artesian Water Company for its well at Wilmington Manor, and to the west at Caravel Farms, and thus appears to represent a mappable unit in a northeast-southwest band from New Castle towards Glasgow. At each location, depth to the top of the formation exceeds 90 feet. Eastward, the Middle Potomac Aquifer is mapped into the Delaware River as existing at a depth of 20 feet below sea level, but its continuity further east cannot be confirmed due to lack of stratigraphic control. Industrial wells installed at Atlas Point, located immediately south of the Delaware Memorial Bridge, were initially thought to have been screened within the Middle Potomac Aquifer. However, heavy mineral analysis conducted on sand cores at 70 feet below sea level at this location by the Delaware Geologic Survey indicated that the sands were from the Columbia Group (Phillips, 1987), which was later identified as the location of a southwest-trending Pleistocene paleochannel in the Columbia Group. Less than ½ mile to the west, the Collins Park well, although drilled to a similar depth, is considered screened within the Middle Potomac Aquifer, indicating that significant communication, perhaps interfingering of the two aquifers, exists in this area.

Even less information is available concerning the geometry of the Lower Potomac Aquifer due to the general lack of deeper boreholes throughout much of the study area. Zhang (1999) however, compiled information from dozens of both state and federal Superfund sites in the southern Wilmington area, and succeeded in identifying and mapping the presence of Potomac sand bodies from the area of the Port of Wilmington to points upstream along the Christina River, to include the "Christina Bend" area of south Wilmington. Throughout much of this area, thin (several feet) lenses of overlapping sands were found onlapping the older crystalline basement rock. These sands thickened towards the southeast to a maximum thickness of 50 ft in the vicinity of the former Halby Chemical Plant (located due west of the Port of Wilmington and south of Cherry Island). In much of the area nearest the Fall Line, areas within, and immediately adjacent the Christina River, the overlying clays were thin or absent, with the Potomac sands in immediate contact with the younger Columbia Formation, Holocene marsh deposits associated with the ancestral river, and/or fill material. Continuity and thickness of the overlying clay increased with increasing distance from the river. At the Halby Chemical Plant, a second sand lense was identified in subcrop, separated by the lower sand by 15-30 feet of variegated Potomac clays. It is unclear whether one, or both, of the referenced sandy zones represent the actual "Lower Potomac Aquifer," as there is little to no information available immediately south of the Zhang study area.

As a result of the extensive use of the Potomac aquifers' usage in New Castle County north of the C&D Canal, there is a large database of information available concerning the aquifer properties and ground-water usage from the aquifers. However, due to the sediment and stratigraphic variability of the Potomac Formation, data is often reported without reference to a specific Potomac Aquifer. Earlier data were simply combined as a set, with resultant means or other statistical measurements reported as representative values. As such, the geologic variability is reflected in the wide range of values for the reported aquifer properties. The compiled range of values represents a function of the lithology, thickness, lateral extent, and degree of interconnection of sand bodies (within the Potomac Formation as well as between the Potomac, Columbia and Magothy Formations) in the area of the well tests (Phillips, 1987).

Averaging data from the various Potomac aquifers, Cushing et. al. (1973) report a range of transmissivity values from 550 up to 3,000 ft^2/day, with specific capacities of 1-13 gpm/ft. Well yields of up to 300 gpm are noted. Sundstrom and Pickett (1971) list results from previous authors which describe specific capacities from 10-50 gpm/ft, but note that these tests were conducted in areas of Potomac subcrop, and thus may likely represent interaction between the Potomac and water-table aquifers. Sundstrom and Pickett (1971) also report transmissivities of 454 - 1,640 ft2/day, and specific capacities of 1.7-6.0 gpm/ft from well tests at the now Motiva refinery in Delaware City, where reportedly "six wells drew water from the lower, and eight that drew water from the upper sand zone of the Potomac." Coefficients of storage from these tests were highly indicative of confined conditions for both of the water-bearing zones, and it was shown that "the upper zone is not markedly affected by pumping from the lower zone and vice versa." Results were also reported from Lower Potomac Aquifer well tests along the Delaware-Maryland border, with a measured specific capacity of 1-2 gpm/ft were obtained where "five major sand zones [were noted] from the surface to a depth of 657 feet, where bed rock was encountered." Results from a Remedial Investigation at Atlas Point by Malcolm Pirnie, Inc. (2000) reported transmissivities ranging from 2,144 up to 8,040 ft^2/day, with an average of 3,350 ft^2/day. However, these high values may indicate interconnection of the Middle Potomac Aquifer with deep channel sands of the Columbia which are known to occur at Atlas Point. In a report summarizing research by the U.S.G.S., Phillips (1987), distinguishes between the three Potomac aquifers, and notes that transmissivities ranged from 454 up to 8,480 ft^2/day, with the highest values from the Upper Potomac Aquifer, and the lowest from the Lower Potomac Aquifer.

Usage of the Potomac aquifers south of the C&D Canal is generally limited by depth and the availability of shallow ground water of sufficient quality and quantity to supply local needs (Cushing, et. al., 1973). However, with increasing growth in the Middletown-Odessa-Summit area, it is anticipated that the Potomac may be tapped in the near future to supply local needs (Bachman and Ferrari, 1995).

In contrast, the Potomac aquifers are used extensively north of the canal, for public, industrial, and to a lesser extent, domestic well purposes. First noted by Sundstrom and Pickett in 1971, Phillips (1987) notes 16 years later the increasing incidence of river water infiltration in areas along the Delaware River, suggesting that overpumping of the aquifers is becoming a serious concern in these areas. Burgeoning growth, a dramatic increase in paved ground surface (which impedes recharge), and contaminant issues further stress utilization of the Potomac aquifers in the greater New Castle area. Ensuring an adequate water supply for the future along the coastal zone in New Castle County may require consideration of development and/or land use controls in recharge areas.

Magothy Aquifer

The Magothy Fm. unconformably overlies the Potomac Formation, and is lithologically distinguishable from the Potomac Formation as it consists almost entirely of sucrosic quartzose sands with some interbedded lignitic silts (Bachman and Ferrari, 1995; Jordan, 1983), but some fining does occur at the top of the formation. The Magothy Formation outcrops along the western side of the C&D Canal, and subcrops in areas immediately south (Sundstrom and Pickett, 1971; Groot, et. al., 1983), dipping gently to the southeast. The top of the Magothy was reported at a depth of 950 feet in Cheswold, 1,225 feet at Dover Air Force Base, and 1,510 feet in Bridgeville. It is laterally persistent in comparison with the individual Potomac sands, and can be mapped from northern New Jersey southwest to Easton, Maryland. Its thickness is relatively uniform throughout the Basin, averaging 50 feet, but it thins, or is missing entirely, in the vicinity of Delaware City. It is unsure whether the absence of the Magothy Formation in this area is due to underlying structure which precluded deposition, or is due to post-depositional erosion (Sundstrom and Pickett, 1971). In many locations, the Magothy Formation is deposited atop sands of the Potomac Formation, and thus the entire sand can be considered as a single aquifer (Cushing, et. al., 1973; Bachman and Ferrari, 1995).

Use of the Magothy or Magothy-Potomac Aquifer is limited in Delaware generally to small-scale domestic and agricultural wells, but is extensively developed to the southwest, in Cambridge and Easton, MD. One of the Town of Middletown's wells is screened in the aquifer at a confined depth of 325 feet. Pump tests on the Middletown well yielded a specific capacity of 1.74 gpm/ft, although Sundstrom and Pickett (1971) report that values less than 1.0 gpm/ft are more common. Transmissivities reported by Groot et. al. (1983) of 4,000 ft^2/day and Cushing, et. al. (1973) of 500 up to 3,000 ft^2/day indicate that the aquifer is capable of yielding water sufficient for large-scale usage.

Englishtown-Mt. Laurel Aquifer System

The aquifers in the marine Upper Cretaceous sediments, consisting of the Merchantville, Englishtown, Marshalltown and Mt. Laurel formations (the first three collectively known as the Matawan Group in New Jersey), are considered to be one hydrostratigraphic division. Lithology of the Merchantville and Marshalltown formations tend to be fine-grained, micaceous and glauconitic, and the deposits are not generally considered to be aquifers, but rather leaky confining beds (Woodruff, 1986). The coarser Englishtown and Mt. Laurel formations consist of a mix of micaceous, glauconitic silty fine sands, and are locally fossiliferous. Discontinuous, thin coarser sand bodies in these units form locally-productive unconfined aquifers in the vicinity of the C&D Canal, where the units subcrop below the sands of the surficial Columbia Formation. Due to the limited geometry of these sands, the transmissive properties of the Englishtown-Mt. Laurel Aquifer System are considered low, and it is unlikely to be extensively developed (Bachman and Ferrari, 1995; Sundstrom and Pickett, 1971). While yield is sufficient for local domestic, agricultural and public uses as reported by Bachman and Ferrari (1995), the only known larger-yield well in the aquifer is operated by the Town of Middletown, with a reported capacity of 150 gpm.

Rancocas Aquifer

The Rancocas Group in Delaware is comprised of two, lithologically-similar formations, the Paleocene Hornerstown and Vincentown formations. Both strata consist of a quartzose and silty glauconitic sand, with increasing glauconite content in the older Hornerstown sediments. Indurated calcareous and ironstone beds are noted (Bachman and Ferrari, 1995). Greensands of the Rancocas Group outcrop in the Middletown-Odessa area, where thicknesses average 35-50 feet, then the sediments dip towards the southeast, where the Rancocas Group loses its identity in the Cheswold area. Thicknesses of 100 feet have been measured between Smyrna and Dover (Sundstrom and Pickett, 1968). The Rancocas aquifer constitutes a locally-productive unconfined aquifer with the overlying Columbia Formation in southern New Castle County, in the vicinity of Odessa and Middletown, and a confined aquifer in areas further to the south and southeast (Bachman and Ferrari, 1995).

Despite the aquifer's extensive use in New Castle County south of the C&D Canal (Townsend-Middletown-Odessa), not much aquifer characterization data exist, which may be due to the fact that much of the aquifer usage is limited to smaller domestic and irrigation wells. Transmissivities reported by Cushing, et. al. (1973) ranged from 300 up to 5,000 ft^2/day, with specific capacities up to 20 gpm/ft. These are notably higher than the specific capacities calculated from aquifer tests on four larger wells screened in the Rancocas Aquifer in Delaware (including the Town of Clayton supply wells) as reported by Sundstrom and Pickett (1971), which ranged from 1.1 up to 4.6 gpm/ft. Older information provided by Rima et. al. (1964) range from 2.3 up to 6.5 gpm/ft, with well yields ranging from 15 up to 330 gpm. Based upon the existing limited information, it is the opinion of both sets of authors that the Rancocas Aquifer has hydraulic properties sufficient for small-yield wells of less than 100 gpm.

Piney Point Aquifer

As stated in earlier sections, deposition of the middle Eocene Piney Point Formation represents the end of the major transgression that began during the Cretaceous, and the last of the glauconitic lithologies within Delmarva. The sediments of the Piney Point Formation consist of a fine to medium glauconitic sand throughout its thickness in the Smyrna-Clayton area south to areas of northern Dover, but the sediments fine substantially from that point southward to a clayey glauconitic silt. As a result of the fining lithology as well as depth, the Piney Point Formation is generally not considered a productive aquifer much farther south than Greenwood or Milford, where the top of the formation lies over 600 feet below ground surface (Leahy, 1982). Similarly, the lithology is fine-grained towards the northeast in southern New Jersey, and southwest, in the time-equivalent Nanjemoy and Aquia formations in Maryland (Leahy, 1982; Keith Robertson, DNREC, personal observation). In the areas where coarser sediments predominate, the aquifer can be very productive, and the Piney Point represents an important aquifer for Smyrna-Clayton-Dover area (Leahy, 1976). The geometry of the Piney Point Formation is an overall lenseate shape, with a thickness of approximately 75-80 feet in its subcrop area in northern Kent County, thickening to 250 feet in the a band from Dover Air Force Base westward, then subsequently fining and thinning to 175 feet as it dips southward towards Milford (Sundstrom and Pickett, 1968; Leahy, 1982).

Due to the aquifer's extensive use in Dover as well as in Cambridge, Maryland to the west, there is ample information on the hydrologic properties of the aquifer throughout its area of use. Transmissivity values generated by numerous pump tests in the Dover area ranged from a low of 800 ft^2/day up to 4,000 ft^2/day. Results from pump tests of two Dover Air Force Base wells provided even higher values of 7,350 ft^2/day and 4,300-5,350 ft^2/day (Leahy, 1982). A lengthy 23-day pump test of the City of Dover wellfield yielded a value of 4,100 ft^2/day (Leahy, 1976). Equally-high values were obtained further south in Woodside (4,400 ft^2/day) and Felton (5,100 ft^2/day). However, as the aquifer thins and fines westward and southward, transmissivities drop substantially, with results of 720 ft^2/day reported from Greensboro, MD, 200 ft^2/day reported from Greenwood and a low of 26 ft^2/day from Milford (Leahy, 1982). Fewer data exist for specific well capacities. Leahy (1982) reports a value of 4.0 gpm/ft from Petersburg, Delaware located southwest of Dover, while Cushing et. al. (1973) reports a wide range of 1 to 25 gpm. It would seem that the Piney Point Aquifer has been developed nearly to its limit in the Dover-Dover Air Force Base area (Leahy, 1982), but additional development should be available for adequately-spaced, smaller-yield wells to the east, south and west.

Chesapeake Group Aquifers

In the Miocene began the second major Tertiary transgression, which resulted in the deposition of the sediments of the thick Chesapeake Group. Within Delaware, the Chesapeake Group has been subdivided into three formations: the Calvert, Choptank and St. Marys Formations. Of the three, only the Calvert and Choptank Formations are considered to contain productive aquifers.

The lower Miocene Calvert Formation subcrops beneath the surficial Pleistocene sediments in the vicinity of the Appoquinimink River and Blackbird Creek in southern New Castle County. Lithology of the Calvert Formation consists principally of a bluish-grey sandy silt, with distinct sand-shell interbeds. Three of the larger, more laterally-continuous sandy zones are considered important aquifers in Kent County. Listed in decreasing age, these sandy zones are the Cheswold, Federalsburg and Frederica Aquifers.

The Choptank Formation has been subdivided by Ramsey (1997) into two subunits. The lower Choptank Formation consists of a basal, clean, and medium to very coarse sand which fines upward into a shelly, fine to medium sands. This lower unit has been informally called the Milford aquifer. The upper, finer beds are generally characterized as fine sandy silts and silty clays, with some scattered shelly sand beds, of which the latter can be locally productive.

Cheswold Aquifer

The Cheswold Aquifer subcrops in a band located immediately south of Smyrna and Clayton which trends southwestward through Kenton. It is truncated eastward of Smyrna by Pleistocene and Holocene sediments associated with the Delaware River (Pickett and Benson, 1977). Thickness of the Cheswold Aquifer varies, up to a maximum 75-100 feet in the vicinity of Frederica, approximately 40 feet in Milford, although it becomes a much less distinct sandy zone in eastern Sussex County, where it is generally not recognizable as a distinct unit (Sundstrom and Pickett, 1968). In the subcrop area, the combined saturated thickness of the Cheswold-Columbia Aquifer exceeds 120 feet (Sundstrom and Pickett, 1968), where it is tapped by the Town of Smyrna for public supply uses. In the Dover area, the Cheswold Aquifer found at a depth interval ranging from 175 feet to 250 feet below ground surface, and is utilized by the City of Dover and Dover Air Force Base. The Cheswold Aquifer has been utilized by the City of Dover as a water source since 1893 (Leahy, 1982).

As a result of its extensive use in Kent and nor Formation thern Sussex County (e.g., Milford), the aquifer characteristics of the Cheswold Aquifer are relatively well-known, and are highly variable. Cushing et. al. (1973) reports well yields ranging from 5 gpm up to 300 gpm, while Sundstrom and Pickett (1969) note yields of less than 100 gpm up to 500 gpm for public supply and industrial wells in the Dover area. Maximum pumping rates of less than 100 gpm were reported in Milford (Sundstrom and Pickett, 1969). Transmissivities vary widely throughout the aquifer's area of use, with the highest values reported for the Dover/Dover Air Force Base region. Values diminish substantially towards the west, southwest and south (Leahy, 1982). Transmissivity ranges from 200 to 4,000 ft^2/day were reported by Cushing et. al. (1973) throughout the area of use. Values from five City of Dover wells, as reported by Leahy (1982) are as follows: 2,200, 2,300, 2,800, 3,900 and 5,300 ft^2/day. Tests from three Dover Air Force Base wells yielded 1,750, 4,550 and 5,300 ft^2/day. As noted previously, transmissivity drops with distance from the Dover area. Talley (1982) reports an estimated 800 ft^2/day in the Milford area, while Leahy (1982) notes the following values: 3,100 ft^2/day (Camden-Wyoming), 400 ft^2/day (Kitts Hummock) and 350 ft^2/day (Magnolia). The variation in specific capacities mimics the variation in transmissivity values. Sundstrom and Pickett (1969) and Cushing et. al. (1973) report a range of values from 0.9 up to 25.4 gpm/ft. The values from the same five aforementioned Dover wells, as reported by Leahy (1982) are: 5.5, 7.9, 10.4, 12.0 and 16.7 gpm/ft, respectively, with notably lower values in areas outside the Dover area: 2.6 (Cheswold), 7.9 (Camden-Wyoming), 1.0 (Kitts Hummock) and 1.0 (Magnolia). The available drawdown has been exceeded in the past by wells pumping from the Cheswold Aquifer in the Dover area, necessitating adjustment in the pumping rates of the City wells (Sundstrom and Pickett, 1971). Continued development in the Dover area will require careful management.

Federalsburg Aquifer

A minor sandy, shelly unit within the Choptank Formation, the Federalsburg Aquifer was recognized by Talley (1982) and others (Ramsey, 1997; Cushing et. al., 1973), and occurs between the older Cheswold Aquifer and the younger, overlying Frederica Aquifer. Less specific information is available about the Federalsburg Aquifer, but it is mapped throughout the Milford Quadrangle in varying thickness (from 6 feet up to 38 feet), and has been identified throughout the Frederica-Cheswold area. Reported yields from several wells installed in these sands ranged from 10 to 400 gpm as reported by Talley (1982) and 4 to 150 gpm by Cushing et. al. (1973). Transmissivity and permeability of the Federalsburg Aquifer vary, but are generally considered low in the Milford area (Talley, 1982). Cushing et. al. (1973) reports values ranging from 450 up to 1,400 ft^2/day. In numerous areas throughout the Delmarva Peninsula, the silty or clayey sections separating the

Federalsburg Aquifer from the Cheswold and Frederica Aquifer are thin, and instead of separating the aquifers, may represent more leaky confining beds, suggesting that there may be some hydraulic communication between them (Cushing et. al., 1973). This may explain the observed variability in aquifer characteristics.

Frederica Aquifer

The Frederica Aquifer represents the youngest regionally-recognized aquifer within the Calvert Formation. It subcrops, similar to the Cheswold Aquifer, as a northeast-southwest-trending band, extending from the area immediately north of Little Creek down towards Sandtown. The lithology of the Frederica Aquifer differs from the underlying Cheswold Aquifer in its increased sand content with a corresponding decrease in shell material, and some gravel. Also similar to the Cheswold Aquifer, the Frederica Aquifer is truncated eastward towards the river by Pleistocene and Holocene fluvial sediments (Pickett and Benson, 1983). Its thickness varies regionally, increasing from a subcrop thickness of approximately 10-12 feet in Dover up to 50 feet in Frederica. In the subcrop area, the combined saturated thickness of the Frederica-Columbia Aquifer can exceed 90 feet (Sundstrom and Pickett, 1968). South of Frederica, the aquifer is not generally recognizable as a distinct unit in western Sussex County, and thins to less than 10 feet in the Milford Area (Sundstrom and Pickett, 1968). While some authors show the Frederica Aquifer, represented as a thin sand immediately below the St. Marys Formation, continuing in areas south of Ocean City, Maryland, Hodges (1984) and others believe the work is tenuous, due to a lack of stratigraphic control. Predictably, aquifer characteristics vary with aquifer thickness. Talley (1982) reports specific capacities ranging from 0.5 to 5.6 gpm/ft with well yields of 10 to 400 gpm, and Cushing et. al. (1973) reports 5 to 200 gpm, with the aquifer supplying adequate water for public, domestic, irrigation and food processing in the Milford area.

Choptank Aquifers

While the sediments of the mid to late Miocene Choptank Formation are considerably sandier than those of the underlying Calvert Formation (Ramsey, 1997), the geometries and aquifer characteristics of the sediments have not been studied, and are generally not utilized to any great degree outside of the Milford area. The sands of the lower Choptank Formation, called the Milford Aquifer, form a mappable unit that can be traced throughout the Frederica-Milford area. In the past, these beds had been confused with the underlying Frederica Aquifer. Recent studies however, have successfully correlated the Frederica sands in the Milford area, and recognized that indeed, the strata represent two separate, albeit thin, aquifers. Thickness of the Milford Aquifer in the Frederica-Milford area is approximately 10 feet (Ramsey, 1997). Little to no aquifer characterization data exists at the present time, despite the relatively extensive use of the Milford Aquifer in the Frederica-Milford area. Similar to the Rancocas Aquifer, this may be due to the fact that much of its use is limited to individual, domestic wells, or perhaps due to the past confusion with the Frederica Aquifer.

A fifth, unnamed aquifer system is recognized within the Chesapeake Group in the central portion of the Delaware Bay and Estuary Basin, which consists of minor, discontinuous sand and shelly sand lenses within the upper Choptank Formation and the overlying St. Marys Formation. These minor aquifers have been noted by Talley (1982), Andres et. al. (1990), and Ramsey (1997) as thin, laterally-discontinuous and frequently in hydraulic connection, making distinction of individual sand bodies difficult. They can be considered locally-productive and important for small irrigation or domestic uses.

Manokin formation

The informal Manokin formation conformably overlies the fine sediments of the St. Marys Formation, the latter acting as a regional confining bed in areas of Kent and Sussex Counties. It comprises the uppermost deposits of the Miocene transgression, and represents the youngest confined aquifer of interest in the Delaware Bay and Estuary Basin. Lithologically, the Manokin consists of lignitic, clayey and silty sands, which fine with depth, and grade into the underlying St. Marys Fm. The sandier upper Manokin represent a locally-important water-bearing zone in Sussex County, particularly along the coast, where it provides water to public supplies (Talley and Andres, 1987). It is overlain throughout its extent by finer sediments of the Bethany Formation and Pleistocene-Holocene fines associated with Delaware River deposits. Like the other Miocene deposits, the Manokin is generally absent eastward of Delaware Route 1, presumably due to Pleistocene erosion and deposition of younger sediments. While the Manokin Aquifer is generally considered confined, the overlying silts and clays may be thin or discontinuous in its updip extent in the Milton-Lewes area, leading to semi-confined, or leaky hydraulic conditions (Hodges, 1984; Andres et. al., 1990). The thickness of the Manokin sands are estimated at 30 feet in the Milton area (Hodges, 1984), and 50 feet to 90 feet thick in the southernmost portion of the basin near Lewes (Andres, 1986).

Much work has recently been conducted on the Manokin, spurred in part, no doubt, by the increased development and population growth of the coastal areas. Much of the hydrologic data was collected from well locations along the seashore areas outside the Delaware Bay and Estuary Basin, and should therefore be considered as being only somewhat representative of the aquifer as a whole. Further, in much of Sussex County, there appears to be interconnection between the Manokin Aquifer and the younger, overlying Ocean City and Pocomoke Aquifers, thus ascribing specific attributes to specific aquifers difficult.

Pump test data provided by Talley and Andres (1987) indicate a transmissivity value from a Lewes well was measured to be an anomalously high 17,420 ft^2/day, with an average of 7,030 ft^2/day throughout its extent in Sussex County (the value given from the Lewes well may represent interconnection between the Manokin and the overlying water table aquifers; the more likely range is 2,500 to 3,500 ft^2/day). Cushing et. al. (1973) reports a range from 950 up to 5,500 ft^2/day, with specific capacities of 1-35 gpm/ft, while Sundstrom and Pickett (1969) report results from several wells along the southern Basin boundary with specific capacities of 34.5 and 44.2 gpm/ft, again suggestive of a "leaky" condition in that area. Aquifer yield as reported by Talley and Andres (1987) ranged from 40 gpm at Five Points to near 1,000 gpm near Millsboro, with an average of 253 gpm (yields of over 1,000 gpm for a confined aquifer are rare, and may indicate aquifer interconnection as discussed above). Andres et. al. (1990) report similar ranges of 300-400 gpm.

2.1.3 SOILS

2.1.3.1 Introduction

Soils have played a critical and largely unrecognized role in terms of where people live and work. Throughout Delaware's history, the establishment of settlements has been made largely on man's perceptions of the inherent value of soils. Documents and history books (Scharf, 1972) hint at the relationship between settlements and the tilth of the soil. Soils were described in terms of their utility, function and their perceived productivity. As in most agrarian-based societies, social status and economic wealth, as well as, land use patterns of development were indeed tied to the soils ability to produce food and fiber and the proximity of landscapes to water transportation. The geography (soils, landscape and direct access to water) of the Delaware Estuary and Bay Basin from the days of pre-colonization to today has provided much of the State's industries and wealth and will continue to do so for a long time to come. Some of the most productive farms in Delaware, some of which are still owned by the original families, are located within the Basin.

Soil can be defined as a living, dynamic resource that supports plant life. It is made up of different size mineral particles (sand, silt, and clay), organic matter, and numerous species of living organisms. Soil has biological, chemical, and physical properties that are always changing. It is a three dimensional body that is bounded by air, water, and rock. While its upper boundary is clear and the margins can be tied to the ability to support vascular plants (including in water), it is the lower boundary that is often debated. Its depth can range from a few inches to several feet.

2.1.3.2 Basic Soil Functions

Soil provides a physical matrix, chemical environment, and biological setting for water, nutrients, air, and heat exchange for living organisms. Soil controls the distribution of rainfall or irrigation water to runoff, infiltration, storage, or deep drainage. Its regulation of water flow affects the movement of soluble materials, such as nitrate nitrogen and pesticides. Soil regulates biological activity, decomposition of organic materials and molecular exchanges between solid, liquid, and gaseous phases. This affects nutrient distribution and usage, plant uptake and growth. Soil acts as a filter to protect the quality of water, air, and other resources. Soil provides mechanical support for living organisms and their structures. While scientists are just now beginning to understand all the complex soil reactions and their relationships, all living organisms depend on these functions for survival.

2.1.3.3 Understanding Soils—Past and Present

Attempts to understand and differentiate soils based on perceived and observed differences in the Basin can be traced back to arbitrary discoveries by many of the local gentry farmers. These early attempts were largely based on visual observations of the soil's ability to produce grain, fiber, and livestock. Many were recorded in the journals of the time.

In 1836, The Third Agricultural Society of New Castle attempted to better understand soils by voting to petition the legislature to begin comprehensive mapping of the surficial geology (soils) in Delaware (Scharf, 1972). The United States Government first authorized attempt to scientifically organize, classify, and delineate soils in this Basin took place in 1917 with the publication of the New Castle County Soil Survey (Morrison et. al., 1917). The 1920 (Dunn et. al., 1920) and 1924 (Snyder et. al., 1924) publications of the Kent and Sussex County Soil Surveys soon followed. This marked the advancement of a national soil survey program and the application of scientific principles to the emerging science of soils. Updates of these first soil surveys were published in 1970 for New Castle County (Matthews et. al., 1970) for Kent County in 1971(Matthews et. al., 1971), and 1974 for Sussex County (Ireland et. al., 1974). While still primarily focused on agriculture, tables on engineering interpretations, limitation of soils for certain land-use categories, and laboratory data were included as they provided soil information for non-traditional users.

The direction of the Soil Survey Program by the United States Natural Resources Conservation Service (NRCS) has remained the same however, the purpose of the organization has dramatically increased since that time. What began as a need to map soils for agricultural reasons has progressed into a need to provide more precise and accurate information for engineering, environmental, and land-use decisions. The soil information that will soon be available will undoubtedly increase the level of overall understanding and allow for better decisions.

2.1.3.4 Pedology of the Coastal Plains—The Setting

The soil and landscapes of the Delaware Bay and Estuary Basin are the product of soil forming factors operating on surficial materials over geologic time. Factors influencing soil formation include parent material (geology), topography (relief), climate (temperature and moisture), vegetation, and living organisms (including man). The degree and intensity of soil development is dependent on the prevailing climate (temperature, moisture and wind) and biological agents (plants, living organisms) which it supports over time to develop soils which reflect the intensity and geographical distribution of the above factors.

Topography in the northern part of the Basin is dominantly undulating and rolling with moderate dissection. In the southern portion of the drainage basin, flatter (slope gradients <1 %) landscapes dominate. This relief affects landscape distribution of soils, landscape distribution of moisture, erosion and alleviation patterns, and degree of soil development (Fanning and Fanning, 1989). The presence and height of the seasonal high water table also correlates to the surface of the landscape.

The parent or initial geological materials also play a pivotal role in soil formation. The majority of the soils from the western edge of the watershed to a north-south tending scarp line developed from fluvial sediments belonging to the Columbia Formation. This Formation is a fluvial deposit consisting of tan, brown, or reddish brown, medium to coarse sand with scattered thin beds of pebbles and gravel. Thin, discontinuous beds of silt and fine sand are also present. In the northern portion, a thin (one to three feet) thickness of loess (silt sized, windblown) sediments blankets the Formation. The loess has given the landscape a gentle and smoother appearance as it blanketed the more eroded and truncated Columbia Formation (Rebertus et. al., 1989).

On the eastern edge of the Basin, ancient marine environments influence the pedology. These include geological formations such as the Hornerstown and the Calvert Formations. South of the fall line of the Piedmont and the Coastal Plains, the non-marine Potomac Formation also has a pronounced influence on the pedology. Tidal wetlands derived from Holocene sediments occupy the flooded and filled ancestral valleys along the eastern edge of the Basin.

Very little interrelationships between soils and local geology are discussed in the literature as both are treated as two separate disciplines. There is a need to further coordinate and facilitate scientific research aimed at relating these two disciplines for the purpose of gaining a better understanding of the pedologic and geological interactions and relationships. This is particularly important in the refinement of sound science principles and the application of future policy decisions in many of the key land use activities and practices.

2.1.3.5 Soil Map Units and Taxonomic Classes

The concept that soil bodies often occur on the landscape in a predictable and repetitive manner allowed for the creation and production of soil maps. Also, since the early days of soil science, the desire to describe and separate soils based on observed features lead to the evolution of a system of organizing and classifying soils. Space limitations in this report prevent a detailed discussion of the taxonomic system used in soils, it is important to impart to the reader that such a framework exists. One of the tools used in Soil Taxonomy is the use of the Munsell TM Color Standards System (www.munsell.com, 2000) which separates colors by hue, value and chroma. Another is the USDA soil textural triangle and classification system (USDA, 1993) which is derived from the percentage of sand, silt and clay in a given horizon. These and other tools and techniques are used to differentiate key soil horizons and nomenclature.

The latest revision of the United States System of Soil Taxonomy (USDA, 1998) and Soil Survey (USDA, 1993) currently provides the basic framework for both mapping and transfer of specific soil information.

A soil map is made up of mapping units that commonly use the soil series name. However, map unit names are not always the same as the soil series. The soil series is a taxonomic unit that quantifies and defines a rigidly defined concept of what a soil classifier observed from vertical observation points. A mapping unit that uses the name of a series implies that the series should be the dominant unit, plus some inclusions of other soils, some similar and other dissimilar to the named soil. The distinction between mapping units and taxonomic units must be kept clearly in mind when using a Soil Survey report.

2.1.3.6 Quality of Soil Mapping

Soil Survey data included in this assessment includes a compilation of soils mapping from the 1960s to the present (*Map 2.1-6 Soil Types*). The soils mapping for the Basin has recently been updated and incorporates mapping conventions employed by USDA-Natural Resources Conservation Service. The protocol provides for the refinement of the soil mapping, including new map units, description of the soil properties and characteristics, and prediction of the behavior of those properties and characteristics for various uses. Soil behavior relies on the evaluated and named soil properties (USDA, 1993). The current mapping techniques use planimetrically correct photography, which allows the data to be easily automated for natural resources geographic information activities. A digitized Soil Survey facilitates better land use decisions and increased or sustained conservation of natural resources. It also provides users with soil maps made to a national standard that are easily registered with other digital maps. Soil databases link soil interpretations to digitized soil maps.

The current NRCS soil mapping program requires that most of these soil map units be field verified using transects to quantify soil composition of individual map units. Most of the soils that are found within these individuals map units have had representative samples characterized by laboratory analysis. The older Soil Surveys primarily focused on agricultural uses of the soil and the soil mapping units were neither as controlled nor as defined. In the older surveys, the agricultural lands were mapped more accurately than urban or forest lands. This difference in mapping detail can easily be determined by comparing soil maps in agricultural lands to soil maps for forest or urban lands. Soil interpretations for forests and urban purposes are poor and at times, inconsistent with the intended use. Most of the soil laboratory data included in the old survey reports was not conducted on soils within Delaware but from adjoining states. Consequently, the quality and merit of the data may not be appropriate for some areas of Delaware.

The compiled Geographical Information System (GIS) soil maps presented for this assessment are from several generations of mapping and may not represent current knowledge or quality standards. However, at the scale presented, the errors correlating the old map units to the new map units are considered minimal. The quality of soils information on GIS maps will continue to increase as the update continues.

2.1.3.7 Generalized Soil Interpretations for the Basin

Soils in the Basin are separated chiefly by two criteria: soil drainage class (Excessively well to very poorly drained) and soil texture (sandy to clayey). *Map 2.1-6 Soil Types* shows thirty-two soil map units in the Basin. The soils map provides a general idea of the soils in the Basin, while providing the location of soils suitable or unsuitable for certain land uses and activities (e.g., farming, septic suitability, wetlands).

Soils are placed in natural drainage classes based on the presence of redoximorphic features that indicate saturated zones within a soil. Redoximorphic features form in the soil as the result of the oxidation-reduction state of the iron commonly found in soil mineralogy. The groundwater in saturated soils normally becomes oxygen deficient (anoxic) and under prolonged conditions the iron will become reduced. One of the indications that this chemical reaction took place is a resulting gray, low chroma or depleted color pattern of the soil matrix. The opposite of this reaction is oxidation of the iron which produces redder hues or concentrations within the soil matrix.

The majority of the poorly and very-poorly-drained soils (*Map 2.1-7 Hydric Soils*) are located within the headwater areas of the creeks, rivers, and within the geomorphic floodplains of these waterbodies. Soils considered as meeting the criteria of hydric, comprise approximately 25 percent of the Basin.

Hydric soils are just one of the three parameters required in the determination of jurisdictional freshwater wetlands regulated by the U.S. Army Corps of Engineers. Wetlands, both freshwater and tidal, are some of the most productive environments and provide a host of benefits, including filtering pollutants from the water, providing protection from flooding, and supplying wildlife habitat. Delaware's natural resources and wetlands are fragile and have been shrinking due to drainage practices, development, highway construction and pollution.

Approximately 40,000 acres of wetlands have been lost in the past 40 years. They are subject to changes by both natural processes and human activities. The effect of the interaction of these forces has meant a 50 percent loss of wetlands in Delaware since the Colonial period. This is a trend that must be addressed and if possible, reversed.

The Basin has a large number of residences and businesses served by on-site wastewater treatment and disposal systems (OWTDS). Subdivisions and lots exist that are currently undeveloped but are recorded and could be developed. Overall, the Basin has slight to moderate limitations for OWTDS. The generalized suitability is shown in one of the appendix maps (*Map 2.1-8 Septic System Suitability*). Areas suitable for gravity-fed treatment and disposal systems comprise approximately 44 percent of the Basin. Marginal areas requiring engineered and alternative treatment and disposal systems total another 13 percent. This leaves approximately 33 percent of the remaining land area that is considered unsuitable for OWTDS. This includes the tidal marsh areas of the Basin.

The siting of an OWTDS is a three-step process. The first step requires a site evaluation. The site evaluation consists of investigating, evaluating, and reporting the basic soil and site conditions, which are used to design the OWTDS. Each report describes specific site conditions or limitations including, but not limited to: isolation and separation distances, slopes, existing wells, cut and fills, and unstable landforms. Each report contains the type of OWTDS that must be constructed and an assigned permeability rate of the soils. This siting procedure ensures that OWTDS are sited and designed by using the following soil properties: permeability, texture, structure, consistence, redoximorphic features, slope, and depth to rock, all of which may limit or hinder proper OWTDS siting and performance.

The second step requires a licensed system designer to design the OWTDS required by the approved site evaluation and to submit the permit application for the approval of the Department. After the permit application is approved, the final step is initiated. A licensed system contractor is hired to construct the OWTDS, which in most cases, is inspected by the Department prior to usage.

All of this soil and permit information is kept on file with the Department and has provided the current NRCS Soil Survey update with vital pedological information. This information is included in an electronic database utilizing a Geographical Information System (GIS) approach which allows the Department to review and comment more effectively on issues of land use changes and impacts. Currently this information, while being available electronically, is difficult to access on a watershed basis or as a GIS map. This would not only facilitate internal program concerns but allow the public more responsive information.

Development will only continue within the Basin. It is expected that the number of OWTDS will steadily increase because residential development is occurring throughout the entire Basin and the cost of public sewers may become impractical. A majority of the soils (61 percent) within the Basin (*Map 2.1-9 Soil Erodibility*) are vulnerable to erosion, both from wind and water. The infiltration capacity and structural stability of a soil influence the inherent erodibility of a soil (K factor). The K factor varies from near 0.1 to about 0.6. Soils with low erodibility tend to be sandy and have a K factor below 0.2. Soils with moderate infiltration capacities and moderate soil stability have K factors of 0.2 to 0.3. Soils that are easily eroded tend to be silty and have K factor greater than 0.3. In the watersheds of the Basin, as in most watersheds, the more erosion prone slopes tend to be adjacent to the streams and their tributaries where down cutting of the landscape is still taking place. Where appropriate, soils were also mapped as being "moderately eroded" and "severely eroded" in their natural state during the course of the Soil Survey. Not surprisingly, the "severely eroded" soils were generally located on the steeper slopes adjacent to the tributaries.

Since the passage of the Delaware Sediment and Stormwater Law in 1991, all new construction activities, which disturb over 5,000 square feet, are required to have an approved Sediment and Stormwater Plan, unless specifically exempted. The program is delegated to various local agencies with oversight by the Department's Sediment and Stormwater Program and uses a "best available practices" approach to control nonpoint source (NPS) pollution associated with construction activities. As part of the overall conservation planning process in the State, the local Conservation Districts and the USDA, NRCS work with agricultural landowners in the Basin to develop and implement plans that are intended to reduce NPS pollution associated with agricultural activities.

When new development projects (residential and commercial) are initiated, most of the soils are cut and graded which makes them highly susceptible to erosion. Delaware's Erosion Control Regulations require areas that will not be disturbed for at least two weeks to be seeded and stabilized. Still, given Delaware's rainfall pattern, a considerable amount of erosion can occur even with control measures. Stormwater structures and management areas have come under close scrutiny recently due to safety concerns. The program will need to continually address these issues and adopt new strategies.

2.1.3.8 Interrelationships of Soils and Environmental Health and Quality

As soil particles erode from the land surface and travel into stream channels during rainfall events, they become temporarily suspended in the water column. From a water supply perspective, this causes turbidity problems, increasing the cost of treatment. Due to their relatively large surface areas, these particles also have a high affinity for other chemically active constituents, such as metals and nutrients. If potential contaminant sources exist in the watershed, eroded soil particles can act as vehicles for transporting toxics to receiving waters. In high enough concentrations, these adsorbed constituents may exceed surface water quality standards.

Pathogens, nutrients, and toxic substances are transported on sediments. Sediment erosion is both an urban and an agricultural problem. Where land is disturbed, erosion occurs. Although urban construction is a temporary land use, active sites are the most intense source of erosion. Urban construction causes ten times the amount of erosion than the next competing source, farming.

Suspended soil particles also act as a source of stress on aquatic life, especially fish. Once the soil particles settle out of suspension and become sediment deposits, impacts to aquatic life are compounded. Bottom dwelling organisms can pass contaminants in the sediments through the food chain to higher level organisms. In some cases this can preclude the consumption of fish from such waters. Thus a direct impact to living resources can lead to an indirect impact on recreational activities. Sediment can also have adverse impacts on habitat. The bottom substrate, on which many organisms rely to live on and lay eggs, can be completely covered with sediment. Wetlands can lose their habitat function and value through the same process.

Perhaps the single most important sediment cross media link is that of land use. In a watershed with a completely wooded land cover, surface erosion is minimal and sediment transport in the stream system is in equilibrium. Once that cover is removed for agricultural production or for construction purposes, the land is exposed to accelerated erosion. Cumulative increases in impervious cover such as roof tops, parking lots and driveways change hydrologic conditions such that streams become unstable and contribute to the sediment loading. Anyone attempting to mitigate the many negative impacts associated with sedimentation must recognize this link with land use.

2.1.4 DATA GAPS AND RECOMMENDATIONS

The reports done for the other Basins within the State identified the need for the Soil Survey effort as well as nutrient management issues. The current Soil Survey is providing the State with more refined soil maps and a greater level of understanding in order to make better decisions. An effective way to deal with the nutrient management issue has also been addressed with the adoption of the Delaware Nutrient Management Commission. The gaps that the Delaware Bay and Estuary Soils Team have identified are the following:

1. Soil and OWTDS information need to be made available in a GIS format with migration of the database into the upcoming Windows 2000 environment. Information also needs to be able to be queried by specific watersheds.

2. Quantification of soil metrics needs to begin. While the update has provided valuable information, future users will be interested in more statistical and empirical data. Map unit purity, spatial variability and pedogenic traits will need to be further refined and available to users.

3. Make land use decisions based on the cumulative impacts of the proposed project and not just a single parameter such as OWTDS considerations. Land use decisions have focused heavily on the proposed singular activity in relation to adjoining land uses and not ecological considerations. This approach does not allow for an adequate assessment of the environmental impacts of human activity. A soils-landscape analysis approach utilizing GIS tools and technology could potentially address this issue.

4. Better education of the construction industry, real estate businesses, land developers and politicians. Improved and more effective coordination between governmental entities and learning institutions (DNREC, NRCS, Universities, Conservation Districts, etc.) has improved the connection between the science of soils and environmental issues.

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2.2 LAND USE AND DEMOGRAPHICS

CONTENTS

Land Use and Demographics

2.2.1 INTRODUCTION

According to the U.S. 2000 Census data, Delaware is the second smallest State in terms of land area at 1,954 square miles. It is the seventh most densely populated State at 401.1 persons per square mile. Delaware's population increased from 666,168 people in 1990 to 783,600 in 2000, an increase of 17.6 percent. Delaware is the thirteenth fastest growing State in America. The average household size is 2.54 persons per household, consistent with the national trend. The Delaware Population Consortium projects the population of Delaware to increase to 938,247 persons by the year 2020. The need to provide housing, infrastructure, and employment for these additional persons is likely to increase pressures on land and other resources. The established growth pattern in Delaware is a suburban sprawl that consumes much more land per capita, and is more costly, on a per capita basis, than traditional mixed-use growth patterns.

2.2.2 LAND USE

Land use, in its most fundamental sense, is the classification of how land is used. Categories including residential, commercial, industrial, and community facilities; recreation; and open space all attempt to define settlement patterns — how land is developed or not developed.

Land-use analysis attempts to show the physiographic relationships between the natural environment and the developed environment, including resource limitations indicated by hydrologic and topographic features, and developable land factors indicated by soils, areas with aquifer recharge potential, and landscape vistas. Other variables are also included in the analysis of land use, such as ownership patterns and economic land values.

The land use maps (*Map 2.2-1 1984 Land Use, Map 2.2-2 1992 Land Use, Map 2.2-3 1997 Land Use* and *Map 2.2-4 2002 Land Use*) summarize data from the 1984, 1992, 1997 and 2002 Land Use - Land Cover surveys. For these maps, the Anderson Land Use Classification System was used to combine the various land uses into the following simplified categories to show their aerial extent: Urban/Residential; Agricultural; Confined Feeding Operation; Brushland/Forest; Water/Wetlands; Barren/Other. It is important to note that some of the differences between the maps are artifacts of the different mapping procedures that were used. For instance, a ten-acre minimum mapping unit was used on the 1982 aerial photography, while a four-acre minimum mapping unit was used in the interpretation of the 1992 and 1997 photography. The minimum mapping unit used on the 2002 aerial photography was 2 acres.

CONTENTS (Continued)

Because of the different technologies available at the time of each mapping exercise, comparisions should not be made between the various mapping years. The only appropriate comparisons that can be made involve the 1992 and 1997 datasets as the same technology and techniques were used for those years (refer to Section 2.2.2.3).

2.2.2.1 Agricultural Preservation Districts

The State legislature has made available tax incentives, regulatory tools, State funding, and intergovernmental coordination to preserve agricultural land. Most comprehensive plans identify currently farmed areas with good soils, and designate them for continued agricultural use. *Map 2.2-5 Agricultural Preservation Districts* shows those lands that are currently enrolled in the State's Agricultural Preservation Program.

When the possibility exists for extending sewer into a particular area, Delaware's agricultural preservation program is not an effective mechanism for protecting such land. Sewer availability is a strong incentive for selection of certain land uses, which are incompatible with permanent agricultural preservation. The Delaware Agricultural Lands Preservation Foundation is incorporated as a non-profit organization whose mission is to to help preserve farmland.

Some advantages of farmland protection include:

- Stabilizing the State economy because it is not affected by the same business cycles, labor strikes, etc. as manufacturing and other sectors;
- Low energy costs for transportation and production where large blocks of agricultural lands are preserved from urban sprawl;
- Smaller costs for public services and facilities;
- Recharge of ground-water systems;
- Recreation and scenic values;
- Cleaner air; and
- Preserving large blocks of farmland provides a system of connected open spaces, and sometimes habitats.

2.2.2.2 Infrastructure-Induced Growth in Agricultural and Conservation Areas

Sewers affect land use by increasing the amount of land available for development. The extent of growth depends on the amount of vacant land the sewer serves and the sewer's excess capacity. Sewers are built to manage waste and as a result maintain or improve water quality. However, sewers can lead to the conversion of large areas of land to residential development. This development, if improperly managed, can have numerous environmental impacts. Examples of these are erosion and sedimentation problems, flash flooding due to more impervious land cover, degradation of stream habitat, and increased air pollution.

2.2.2.3 Analysis and Summary

As illustrated in *Map 2.2-2 1992 Land Use* and *Map 2.2-3 1997 Land Use* showing Delaware Bay and Estuary Basin land use/land cover in 1992 and in 1997, respectively, the Anderson Land-Use Classification System separates land uses into the following categories: Urban Built-Up, Agriculture, Brushland, Rangeland, Forestland, Wetlands, Water, and Barren Land. For the purposes of this report, Urban Built-Up includes residential, commercial, and industrial areas, as well as transportation, utilities, mixed urban, and other undifferentiated urban, institutional, and recreational areas. Agricultural land is a separate category. Forestland, Brushland, Rangeland, and Barren Land (e.g., beaches, inland sandy areas, extraction areas, etc.) are combined under the Forest/Open Land category. Wetlands and Water also have been combined since relative to other categories of land use, this category changed little over the study period. These categories were compared to one another in the tables found in this section.

TABLE 2.2-1 GROSS LAND USE CHANGES, STATE OF DELAWARE, 1992-1997

	1992 (acres)	1997 (acres)	Change (Acres)	Change (%)
Developed	188,272.43	214,547.89	26,275.46	13.96
Agricultural/Forest	776,719.27	746,424.30	-30,294.97	-3.90
Water	45,898.36	47,380.69	1,482.34	3.23
Wetlands	245,038.79	242,684.63	-2,354.16	-0.96
Other	27,886.93	32,729.11	4,842.18	17.36

As noted earlier, because of the different technologies available at the time of each mapping exercise (i.e., 1984, 1992, 1997, 2002), comparisions should not be made between the various mapping years. The only appropriate comparisons that can be made involve the 1992 and 1997 datasets as the same technology and techniques were used for those years.

Delaware lost agricultural land and forests in the five years between 1992 and 1997, continuing a trend seen between 1984 and 1992. The State gained in "developed" uses (residential, urban, commercial, industrial, transportation, government and utility) over the same period. Developed uses grew by almost 14 percent over the period, while the amount of agricultural and forested land was down by nearly four percent (*Table 2.2-1*).

The largest change, by percentage, was in the "other" category, which includes brushland, rangeland, barren land and other uses. The largest portion of this gain was seen in Sussex County. This change may reflect an interpretation of forested lands that had been harvested for timber prior to 1992, and were growing back through a "scrub" or "brush" phase in 1997.

The 1992 and 1997 data also show a growth in water areas of over three percent. This may indicate a change in interpretation or may be due to differences in the relative wetness of the years in which the aerial photography was taken. There is, however, also a slight decrease in wetland areas. This may reinforce the theory that the water difference is due to interpretation.

Table 2.2-2 Distribution of Land Use, State of Delaware, 1992-1997

	1992	1997
Developed	14.67%	16.71%
Agricultural/Forest	60.50%	58.14%
Water	3.58%	3.69%
Wetlands	19.09%	18.90%
Other	2.17%	2.55%

Agriculture and forest cover retained the largest combined share of land use in the State though this category dropped from almost 61 percent in 1992 to just over 58 percent of land use in Delaware in 1997. Wetland areas remained the second largest share of land use, changing only slightly over the period. Developed land uses grew from almost 15 percent of the State in 1992 to almost 17 percent in 1997 (*Table 2.2-2*).

Other categories remained essentially the same, in terms of their share of land use, over the period.

In the Delaware Bay and Estuary Basins from 1992 to 1997, agricultural land, barren land, forestland, and wetlands lost a combined 11,808 acres, while urban lands gained 10,792 acres. One can infer from the changes in land use that previously undeveloped lands were converted to developed lands (*Table 2.2-3*).

Table 2.2-4 represents the land use calculations for the various classes (represented in percentage) for the years 1984, 1992, 1997 and 2002.

2.2.3 THE SHAPING DELAWARE'S FUTURE REPORT – DELAWARE IN THE YEAR 2020

In late 1994 and early 1995, Governor Carper's Cabinet Committee on State Planning Issues undertook an extensive effort to determine Delawareans' views of what their State should look like in the year 2020. The Committee gathered opinions on development, economic, infrastructure and quality of life issues.

In the upcoming years, most Delawareans hope to recreate strong communities and enhance their quality of life. Communities would build upon the social, economic and the environmental diversity of Delaware. Although opinions were varied and often contradictory, most citizens generally envisioned the future as being proactively created, guided and shaped by State and local governments, businesses and the public.

2.2.3.1 The Guiding Principles

Highlights of "Shaping Delaware's Future" are summarized below.

- Housing and business development is focused in existing communities and in clearly defined "growth" areas of the State, with limited development occurring outside of these areas;
- People live in communities where they have options to using their automobiles for getting to work, shopping, and recreational activities;
- New housing and business developments are designed to be visually appealing and minimize the negative impacts on the environment;
- Redevelopment brings stronger economies and growing populations to existing cities and towns throughout the State;
- A wide variety of good paying jobs are available which match the abilities of Delawareans;
- Agriculture and tourism remain a major part of the State's economy;
- The cost of roads, water, sewage and other such public facilities and services is minimized by focusing these investments in existing or planned communities;
- Technological advances are used to make the production and delivery of facilities and services more efficient;

TABLE 2.2-3 LAND USE CHANGES IN THE DELAWARE BAY & ESTUARY BASINS, 1992-1997

	1992 (acres)	1997 (acres)	Change (Acres)	Change (%)
Agriculture	241,691	232,737	-8,954	-3.7
Barren Land	7,279	6,706	-573	-7.9
Forest Land	66,109	64,183	-1,926	-2.9
Rangeland	4,823	5,097	274	5.7
Urban	63,636	74,428	10,792	17.0
Water	15,134	15,807	673	4.4
Wetlands	109057	108,702	-355	-0.3

- Public policy decisions are made in an open and coordinated fashion among State, county and municipal levels of government;
- All citizens have improved housing, health care and education opportunities; and
- The environmental and cultural amenities of the State are protected and enhanced.

Specific goals were developed by the Committee on State Planning Issues to achieve the findings above. These goals include:

- Direct investment and future development to existing communities, urban concentrations, and growth areas;
- Protect important farmlands and critical natural resource areas;
- Improve housing quality, variety, and affordability for all income groups;
- Ensure objective measurement of long-term community effects of land-use policies and infrastructure investments;
- Streamline regulatory processes and provide flexible incentives and disincentives to encourage development in desired areas;
- Encourage redevelopment and improve the livability of existing communities and urban areas, and guide new employment into underused commercial and industrial sites;
- Provide high quality employment opportunities for citizens with various skill levels to retain and attract a diverse economic base;
- Protect the State's water supplies, open spaces, farmlands and communities by encouraging revitalization of existing water and wastewater systems and the construction of new systems;
- Promote mobility for people and goods through a balanced system of transportation options;
- Improve access to educational opportunities, health care, and human services for all Delawareans; and
- Coordinate public policy planning and decisions among the State, counties, and municipalities.

2.2.3.2 Managing Growth - Strategies for State Policies and Spending

These Strategies were created for the Governor's Cabinet Committee on State Planning Issues as a tool to help manage new growth in Delaware while revitalizing existing towns and cities and protecting the State's environment and unique quality of life.

The Strategies are predicated on the fact that, while local governments - county and municipal - exercise control over land-use decisions in their own jurisdictions, State investment and policy decisions can influence land use and the pattern and pace of growth.

An early draft was adopted on an interim basis in January of 1999. A more detailed draft was put out for public comment in late September of 1999. After many workshops, meetings with county and municipal leaders, extensive comments and revisions, and three public hearings, the Cabinet Committee on State Planning Issues adopted the Strategies document on December 23, 1999.

2.2.3.3 All Across Delaware, People Are Talking About Growth

No matter how they differ, communities from center city Wilmington to downtown Dover, from historic Seaford to the beachfront resort communities, are facing the same question: How can we handle the myriad challenges that arise from the First State's phenomenal increase in population and land development?

These increases present both opportunities and problems: more jobs, but more traffic; greater housing choices, but fewer acres of farmland; a gain in shopping options, but a loss of community character; a larger pool of potential employees for businesses, but a poorer quality of life for those employees.

2.2.3.4 The Pace of Change

The mix of benefits and difficulties that result from growth are nothing new - they have been part of the "suburbanization" of America since the 1950s, when an exodus began from urban areas (the traditional population centers) to outlying areas.

Although the pace of change was somewhat slower in Delaware, it has accelerated in recent years at a startling pace. Here are a few indicators of that growth:

Table 2.2-4 Land Use Calculations for the Delaware Bay and Estuary Basin – 1984, 1992, 1997 and 2002

Class	Percent
1984	
Other	0.13
Agriculture	51.04
Barren Land	0.16
Brushland/Forest	23.48
Other Open	0.01
Urban Built-Up	8.03
Water/Wetland	17.15
1992	
Other	0.02
Agriculture	47.62
Barren	1.43
Rangeland/Forestland	13.98
Urban Residential	12.54
Water/Wetlands	24.41
1997	
Other	0.03
Agriculture	45.87
Barren	1.32
Rangeland/Forestland	13.65
Urban/Residential	14.66
Water/Wetlands	24.47
2002	
Urban/Resident	17.03
Agriculture	44.05
Brushland/Forest	13.17
Water/Wetland	24.66
Barren	1.09

- Delaware's population increased by almost 67 percent between 1960 and 1998.
- Most of that increase was in unincorporated areas, where population doubled.
- Delaware's residential areas grew by almost 50 percent between 1984 and 1992.
- Commercial and industrial uses increased by more than 60 percent during that period.
- The State lost 21 percent of its farmland to development between 1970 and 1997.
- The Delaware Population Consortium predicts that 95,000 more people will call Delaware home in the next two decades, a growth rate of more than 12 percent. Much of the growth will come from people moving into Delaware, attracted by employment, quality of life, low taxes and prices, and in coastal areas by natural amenities.
- Over the 30-year span between 1990 and 2020, according to the Population Consortium's projections, Kent County will have grown by nearly 32 percent, New Castle County by almost 21 percent, and Sussex County – the fastest-growing county – by just over 56 percent.
- Households, the consumers of land, will grow almost twice as fast as population – almost 22 percent – as a result of declining family size, greater longevity, and growing numbers of singles.
- With people come vehicles and both total numbers of vehicles and the miles they are driven are increasing faster than population growth. Total miles driven grew by 4.5 times the rate of population growth in the 1980s and show no signs of slowing in the future, primarily as a result of the much-dispersed way various uses and services are located.

Over the last four decades, the First State has shifted from a place with strong vibrant cities and towns supported by a thriving rural sector to a sprawling suburban place whose overall quality of life and rural economy are in danger. That trend is likely to continue, unless steps are taken now to better manage the State's inevitable population growth.

The trend in Delaware has been toward growth in unincorporated areas outside towns. In 1960, Delaware's population was more evenly distributed between incorporated places (cities and towns) and unincorporated, rural areas. According to the 1960 census, more than 39 percent of Delawareans lived in town and cities and almost 61 percent lived outside of towns. According to the latest population estimates from the U.S. Census Bureau, the population in incorporated places had fallen to less than 28 percent of Delawareans. More than 72 percent now live outside town and city limits.

2.2.3.5 Strip Development

Strip development is a development pattern that occurs in rural areas along roads. Typically, this development is a form of sprawl in which land is converted from natural or agricultural uses to small lot residential homes. Usually these homes line a road on one-acre lots with one driveway per home. Both water and wastewater are the responsibility of the homeowner who has little option but to use an on-site septic tank for wastewater disposal and a shallow well for water supply. This type of development is common in the Delaware Bay and Estuary Basin. This pattern is evident by the distribution of domestic septic systems shown on *Map 2.2-6 Strip Development and Growth Patterns*.

Strip development is generally considered a poor form of development as it causes a loss in highway capacity with its one driveway per home ratio; takes productive farmland out of production; puts demands on public services (school buses, State police, etc.); contributes to ground-water pollution from the septic tank; and increases air pollution due to longer car trips to commercial areas to acquire needed goods and services.

2.2.3.6 What Can We Do to Manage This Explosive Growth?

Although decisions concerning land use remain at the local and county level, the State can influence the way development occurs through its spending and management policies. By making wise decisions about building and managing highways, water and sewer systems, and other public facilities (commonly called "infrastructure"), the State can reduce the negative effects of poorly-planned, unfocused growth.

By promoting and supporting development and redevelopment in places where adequate infrastructure exists or is planned, the State can manage congestion, preserve farmland, enhance community character and protect important state natural resources. In short, it can preserve Delaware's high quality of life.

To do so, State agencies have to work closely with county and municipal governments, and all parties need guidelines to help make smart land-use decisions. To that end, the Cabinet Committee on State Planning Issues has developed a set of strategies to guide State spending and policies.

2.2.3.7 Growth Management Strategies

New development should be directed to where it makes the most economic, environmental and social sense. The strategies for doing so are based on common-sense distinctions between highly developed areas, rural areas and the transition areas between them. Although most decisions concerning land use remain at the local and county level, the state can influence the way development occurs through its spending and management policies. By making sensible decisions about building and managing highways, water and sewer systems, and other public facilities (commonly called "infrastructure"), the state can reduce the negative effects of unfocused growth.

By promoting development and redevelopment in places where adequate infrastructure exists or is planned, the state can reduce congestion, preserve farmland, enhance community character and protect important state resources. In short, it can preserve Delaware's high quality of life. To do so, state agencies have to work closely with county and municipal governments. *Map 2.2-7 State Investment Areas* depicts the preferred areas for future growth within the Basin.

In workshops conducted by the Cabinet Committee on State Planning Issues, Delawareans said they want well-planned, efficient and orderly growth. Accomplishing that requires new development to be directed to where it makes the most economic, environmental and social sense. The strategies for doing so are based on common-sense distinctions between highly developed cities and towns, less developed rural areas and the developing transition zones between them. Because the types of development are so different, spending and policies for each type would also differ.

Trying to neatly fit the many, diverse areas of Delaware into just a handful of categories is impossible, but this document will use the following broad terms as convenient shorthand for the range of developed-through-undeveloped areas:

Communities -- In these areas where population is concentrated, commerce is bustling and a wide range of housing types already exists, State policies should encourage redevelopment and reinvestment. They should also increase transportation options, improve water and wastewater systems, and ensure community identity and vitality.

Urban centers -- In more urban, city areas, the State will pursue the same goals listed under "communities" as well as specific strategies that address the special conditions of these places with major concentrations of population and economic, governmental, academic, and cultural activities.

Employment centers -- In these specially designated areas, the State will promote new economic development, and a balance between workplaces and residences.

Developing areas -- In these zones between development centers and rural areas, State investments and policies will be targeted to accommodate existing development and orderly growth. State investments should link development plans to available infrastructure, encourage interconnections between developments, promote a variety of housing types and protect natural resources.

Environmentally sensitive developing areas -- In these areas surrounding the Inland Bays, where development is putting pressure on the both the natural environment and infrastructure such as roads, the State will seek a balance between resource protection and sustainable growth.

Secondary developing areas -- In these areas designated for growth by county plans, but not included in the State's developing areas, the State will promote efficient, orderly development and the coordinated phasing of infrastructure investment, consistent with the extent and timing of future growth, and within the limitations of State financial resources.

Rural areas -- In these historically open areas, State policies should encourage the preservation of a rural lifestyle and discourage new development. Spending on transportation, water and wastewater systems should be limited to what is needed to alleviate health and environmental risks and to accommodate regional trips, with little additional capacity that would encourage further development. State policies should protect farmlands and natural areas, while also promoting the revitalization and enhancement of small rural communities.

2.2.3.8 How Will These Strategies Be Used?

The State will use these strategies to make decisions such as the allocation of new State funding for farmland preservation, road construction, open-space preservation, transportation investments, State-supported housing development, and water and wastewater financing. The Strategies will also serve as a guide for review and, if necessary, revision of existing State policies. They also provide a framework for State comments on local comprehensive planning and land use decisions.

The State Strategies will be useful tools for county and local governments, but they are not intended to restrict county and municipal authority in land use decisions. The Strategies will be a critical component of the information considered for county comprehensive plans, and they will be part of the State guidance for municipal planning and for intergovernmental coordination between counties and municipalities.

These strategies are not intended to replace local land use plans. The State is not determining where the counties or municipalities can or cannot exercise their responsibilities, or where they should allow or not allow development to occur. The Strategies do not restrict landowners' rights to use or develop their lands nor do they restrict a purchaser's option to live anywhere desired. The Strategies do create a framework for where the State will most likely allocate its resources and focus State program efforts.

The criteria that are the basis for the Strategies will be continually refined, and the Strategies will be reviewed and, if necessary, revised every five years.

2.2.3.9 Working for the Future

The Strategies for Managing Growth in 21st Century Delaware are based on these basic premises:

- State actions influence development, and affect quality of life;
- State spending should promote quality and efficiency, not sprawl; and
- State policies should foster order and resource protection, not degradation.

Putting these ideas into action requires a clear vision of where development should, and should not, be directed. Using carefully thought-out strategies, the State can influence where growth occurs. County governments will be able to plan for growth with a clear understanding of where State resources will be most readily available. Municipal governments will be able to plan for the growth of their cities and towns with a clear knowledge of how the State and county governments view the areas around their borders.

People want to live in Delaware, and we all understand why. We can welcome more Delawareans, more new businesses, more new jobs, and still maintain our high quality of life - if we plan it that way.

Livable Delaware

Livable Delaware is a positive, proactive strategy that seeks to curb sprawl and direct growth to areas where the state, counties and local governments are most prepared for it in terms of infrastructure investment and thoughtful planning. It builds on the foundation laid by the Strategies for State Policies and Spending, which were adopted in 1999.

Livable Delaware is not anti-growth and attempts to use "carrots" rather than "sticks" to guide growth.

The State's Role in Land Use

Delaware's population is projected to grow by more than 200,000 people between now and 2030. The state of Delaware has a stake in how and where growth occurs. Unlike most other states, Delaware provides most services and infrastructure throughout the state, social services, prisons, roads and transit, police forc, about 70 percent of school funding, 50 percent of library construction funding, and 60 percent of paramedic funding.

Governor Minner believes that state government's responsibility is to provide these services and infrastructure efficiently, not haphazardly. Sprawl wastes taxpayers' money.

What Is Wrong with Sprawl?

A 2001 Centers for Disease Control study defines sprawl as "uncontrolled, poorly planned, low-density and single-use community growth." Besides wasting taxpayers' money, sprawl damages our quality of life in Delaware in the following ways:

- Contributes to the loss of about 3,500 acres of farmland a year (Delaware Department of Agriculture);
- Aggravates traffic congestion and air pollution;
- Lengthens response times for emergency responders;
- Destroys natural habitat and contributes to groundwater depletion and pollution;
- Contributes to flooding and drought problems because of the growth in impervious surfaces (buildings, roads, parking lots); and
- Contributes to a sedentary and unhealthy lifestyle

2.2.3.10 DNREC and Comprehensive Planning

The mission of the Department of Natural Resources and Environmental Control is:

"to ensure the wise management, conservation, and enhancement of the state's natural resources, protect public health and the environment, provide quality outdoor recreation, improve the quality of life, and educate the public on historic, cultural, and natural resource use, requirements, and issues."

The Department accomplishes this mission through a myriad of regulatory and non-regulatory programs designed to control emissions to the air, land, and water, and to preserve and maintain our natural resource heritage. Livable Delaware has as its cornerstone the preservation and enhancement of our quality of life. "Quality of life," however, encompasses a wide variety of issues from the air we breathe, the water we drink, public safety, education, recreational, cultural, and employment opportunities, and many others.

In the Department's view, however, the environment and Delaware's ability to enjoy and recreate within that environment are paramount to the success of Livable Delaware. Without clean air, clean water, and a healthy ecosystem, quality of life is greatly diminished. Therefore, the activities of the Department in accomplishing its mission are crucial to the success of Livable Delaware.

On March 22, 2001, Governor Minner unveiled the Livable Delaware growth initiative for the First State. For DNREC, Livable Delaware involves every Division within the organization and every employee in the Department. Virtually all of the Department's programs, in one form or another, contribute to Delaware's "quality of life": clean air, clean water, unspoiled landscapes, biodiversity, open space, and outdoor recreation opportunities, to name a few. However, the focus of executing Executive Order No. 14, that is, examining the Department's policies, programs, and regulations in light of "Shaping Delaware's Future: Managing Growth in 21st Century Delaware, Strategies for State Policies and Spending" ("the Strategies"), has been to identify programs that are, or can be, utilized to direct growth and control sprawl.

DNREC has a vested interest in how growth occurs statewide. Increasing population, employment and commerce invariably translate into increased stresses on our natural environment, through increased water resource needs, wastewater generation, non-point source pollution, air pollution and other impacts. Growth and sprawl also have negative consequences for maintenance of open spaces and recreational opportunities, habitat protection, biodiversity and preservation of the historically rural character of much of Delaware.

2.2.3.11 Growth and Water Quality

Clean and plentiful water supplies for consumption, swimming, fishing, agriculture and aesthetics are critical to Delaware's continued prosperity and yet nearly 85% of our surface water bodies do not meet federal or state water quality standards. For the past five years or more, DNREC has been actively developing what is termed Total Maximum Daily Loads, or "TMDLs," a major strategic priority of the Department with respect to water quality. The Federal Clean Water Act requires States to develop these TMDLs for water bodies in which existing pollution control activities are not sufficient to attain water quality standards. A TMDL sets a limit on the amount of pollutants that can be discharged into a water body such that water quality can improve and the standards can eventually be met. Achievement of TMDL targets is in large part predicated on where growth occurs and how we manage the water pollutants that accompany that growth. The availability of regional sewer systems, discharges from wastewater treatment plants, location and density of individual on-site septic systems, and the management of stormwater are all factors which impact our ability to achieve TMDLs.

2.2.3.12 Growth and Air Quality

Another critical environmental issue directly impacted by growth and sprawl is clean air. Delaware has a serious problem with ground-level ozone and is in violation of the federal ozone standard. The 1990 federal Clean Air Act Amendments contain provisions for the attainment and maintenance of the National Ambient Air Quality Standard for ozone and prescribe certain actions we must take to achieve the standard and consequences should we fail to meet it. The Act's provisions aside, clean air is important for the health and well-being of Delawareans and is a critical requirement for our continued growth and prosperity. Growth and prosperity, however, also exacerbate our air pollution problems. More people and more sprawl translate into more air pollution: from cars, energy generating facilities, lawn mowers, boats, leaf blowers and all the other trappings of prosperity. Attainment of the ozone standard will require that we try to minimize air pollution by directing growth into areas that will allow us proximity to employment centers, schools and recreational facilities.

2.2.3.13 Growth and Water Supplies

Water supply is another overarching and serious concern for DNREC and for future growth in Delaware. Maintaining adequate water supply capabilities for domestic consumption, industrial use, habitat and fisheries protection, and agriculture, especially during times of drought, has been a challenge for Delaware. Increasing population puts additional pressure on limited resources and sprawl puts additional strain on distribution and treatment infrastructure. Protection from contamination and a thorough understanding of the occurrence and availability of our State's limited resources are critical to maintaining a Livable Delaware.

2.2.3.14 Growth and Land Management

DNREC owns, maintains, leases, or in some manner preserves a great deal of land, either through fee simple acquisition or via conservation or other easements. In most cases the Department's land holdings amount to permanent preservation and removal of those lands from the pressures of development. This is a straightforward technique for directing growth, however, it is not the only means and it is very costly. Private land owners, other conservation-oriented organizations and other units of government can and have done much to remove land from the development picture. More land will inevitably be purchased or protected by these means, and additional resources will be required.

2.2.3.15 The Connection between Biodiversity and Land Use

Rapid growth – especially the suburban growth that has occurred in Delaware – has a profound effect on biological diversity. While poorly-planned growth leads to the direct loss of farmland and forestland, it also fragments and degrades remaining forests and wetlands. Once fragmented and disturbed, vegetated communities become more susceptible to degradation by the establishment of invasive exotic species.

One of the reasons for such a disproportionately large loss of the State's forests, wetlands, and agricultural land is the sprawling character of Delaware's growth. This growth has been made possible by the cumulative effects of many State transportation and infrastructure decisions. Traditionally, increasing automobile use and traffic has been accommodated by the development of more roads and highways. The resulting network of roadways has enabled sprawling growth to penetrate virtually every corner of Delaware, making the protection of the State's natural heritage that much more difficult.

How people and institutions develop and manage the land will determine the ultimate success or failure of biological diversity conservation in Delaware. Effective conservation must occur at two levels – on individual parcels of land and on a regional basis. By focusing on an individual parcel of land or segment of a stream, decisions can be made that affect species success on that parcel or segment. At the same time, a regional perspective is important because many species depend upon large areas, and because the cumulative impact of human activities across separately owned tracts of land can promote the success – or cause the failure – of conservation efforts.

2.2.4 DATA GAPS AND RECOMMENDATIONS

Below are a number of key policy recommendations taken from *Protecting Delaware's Natural Heritage: Tools for Biodiversity Conservation*. These recommendations identify ways biodiversity conservation and restoration can be enhanced through reinterpreting existing laws, fine-tuning management practices, working cooperatively to promote innovative tax incentive and voluntary cost-share programs already available in the State, or adopting new laws. Which of these challenges Delaware chooses to embrace is for its dedicated citizens, legislators, business leaders, and natural resource professionals to decide. The chapter references at the end of each recommendation identify where the background material supporting the recommendation can be found.

1. Delaware should exercise its authority to deny infrastructure and development funding for projects that are inconsistent with State development policies, including development outside of designated growth areas. The Quality of Life Act should be modified to require (rather than merely allow) the state to deny funding for infrastructure projects whenever a proposed action is inconsistent with State development policies. (Ch. 3)

2. Amend existing county comprehensive plans to ensure that they are consistent with the State's development priorities. State designated growth and preservation areas are required by law to be reflected in comprehensive plans at the county level. Require counties to develop zoning maps that are in accord with their comprehensive plans. Areas designated as growth and preservation areas in the county comprehensive plans should be reflected as such in the zoning maps. (Ch. 3)

3. The Department of Natural Resources and Environmental Control should move quickly to meet its legal obligations under the Land Protection Act by providing counties with detailed maps of State Resource Areas (SRAs). Based on

these maps, all three Delaware counties should comply with the Land Protection Act by adopting overlay zoning ordinances and environmental design standards to protect SRAs. (Ch. 3 & Ch. 5)

4. Amend the State tidal wetlands law to provide protection for buffer areas adjacent to tidal wetlands. The law should also be amended to require local governments to adopt the appropriate tools to protect critical wetlands and buffers. (Ch. 4)

5. Secure a stable annual source of funding for the Open Space Program and the Agricultural Lands Preservation Program. (Ch. 5)

6. Revise the Land Protection Act to create a matching grant program within the Open Space Program. Matching funds could be allocated to local governments and conservation organizations to acquire open space in areas consistent with the State's conservation goals. (Ch. 5)

7. Revise the scoring system of the Agricultural Lands Preservation Act to give increased weight to wetlands, forests, areas in close proximity to open space, wind-breaks, buffer strips, and other natural amenities on agricultural lands. (Ch. 5)

8. Amend the Agricultural Preservation Program to provide greater incentives to district landowners to engage in environmentally beneficial practices. Provide enrolled landowners with tax credits for implementing agricultural conservation management plans. The Delaware Department of Agriculture, U.S. Department of Agriculture, and U.S. Fish and Wildlife Service should coordinate to give additional preference to landowners enrolled in Agricultural Preservation Districts to encourage them to apply for cost-share funding through existing Farm Bill and wildlife enhancement programs. (Ch. 5)

9. Develop management plans for each of Delaware's public land holdings that address biodiversity conservation and restoration goals. Require regular updates to reflect new trends in wildlife and recreational use, include regular updates on exotic species, ensure that each agency's constituents are being served, and ensure that management activities reflect current scientific understanding and do not adversely affect species diversity. (Ch. 6)

10. Amend Delaware's Farmland Assessment Act to allow lands managed for conservation purposes to be eligible for property assessment at current use, as are lands that sell agricultural, horticultural, or forestry products. (Ch. 7)

11. The U.S. Department of Agriculture's Natural Resources Conservation Service, Delaware Department of Natural Resources and Environmental Control, Delaware Department of Agriculture, and other State and local natural resource agencies should coordinate efforts to promote voluntary private land conservation programs that benefit biodiversity. (Ch. 7)

2.2.5 REFERENCES

Environmental Law Institute, 1999, *Protecting Delaware's Natural Heritage: Tools for Biodiversity Conservation* 149pp.

Shaping Delaware's Future: Managing Growth in 21st Century Delaware; Approved 12-23-99. The Governor's Cabinet Committee on State Planning Issues.

2.3 CONTAMINANTS

2.3.1 INTRODUCTION

A contaminant source is a site that has released or has the potential to release pollutants to the air, soil, ground water, surface water, or sediment. Pollutants include toxic chemicals, volatile organic compounds (VOCs), particulates, salt, soap (surfactants), bacteria, nutrients (such as phosphorus and nitrogen), sediments, heat, and so forth.

Almost anything can be a pollutant. For example, the Clean Water Act states, "The term 'pollution' means the man-made or man-induced alteration of the chemical, physical, biological and radiological integrity of water." Anything becomes a pollutant when it causes or contributes to an environmental problem.

Of course, human activities like manufacturing produce gaseous, solid, and liquid wastes. The transport and ultimate fate of wastes are key issues for understanding past, present, and potential future causes of environmental problems. Rain can remove gaseous wastes from the atmosphere, but may transport those wastes into the ground and waterways. Manufacturing solid and liquid wastes do not contaminate the environment if they are safely contained in a landfill with an impermeable lining below and cap above. However, if the landfill leaks then those wastes can become problems. Rain infiltration into a leaking landfill can transport those wastes into ground water; ground-water flow can then transport those wastes to wells or nearby streams.

Federal and State environmental regulations address "attainment" for air and water quality, meaning that pollution levels are low enough for the air and water to be safe to use. Environmental regulators usually focus on the biggest pollution problems first, and on areas where they have legal jurisdiction. Contaminant sources associated with non-attainment of air or water-quality requirements are usually the very top priorities. However, regulatory authority and efforts are often limited to industrial and municipal sources of pollutants.

For example, in many streams in the Basin, nutrient over enrichment is a cause of non-attainment. Past regulatory efforts to eliminate nutrient pollution in waterways were limited to controlling wastewater discharges from industries and town wastewater treatment plants. More and more, efforts are being focused on educating people and developing alternatives to help control nutrient pollution from activities of individual citizens (fertilizing crops and lawns, for example). In aggregate, these activities contribute large amounts of untreated nutrient discharges to streams.

CONTENTS

CONTAMINANTS

CONTENTS (Continued)

Proper disposal, treatment, or beneficial use of wastes greatly reduces their chance to become environmental problems. At the least, wastes should be disposed to well-contained facilities, like landfills. Treatment can biodegrade many organic wastes into harmless substances. Some wastewater treatment plant and agricultural wastes can be used beneficially as fertilizer, taking care that it will not be transported into ground water by over-applying, or into streams by rain runoff. Pollution prevention efforts go even further by reducing the amount of waste produced, or recycling and reusing wastes.

Lastly, contaminants can be from historical, existing, and new sources. Old landfills may have linings that are inadequate by today's standards; past pollutant discharges may have accumulated in ground water or in stream sediments. Current discharges from industrial, municipal, agricultural, and even individual activities can contribute to problems. Given limited resources, participants must act responsibly and prioritize environmental improvement efforts to address known current problems, with a keen eye on potential new problems and sources.

2.3.2 SOURCES

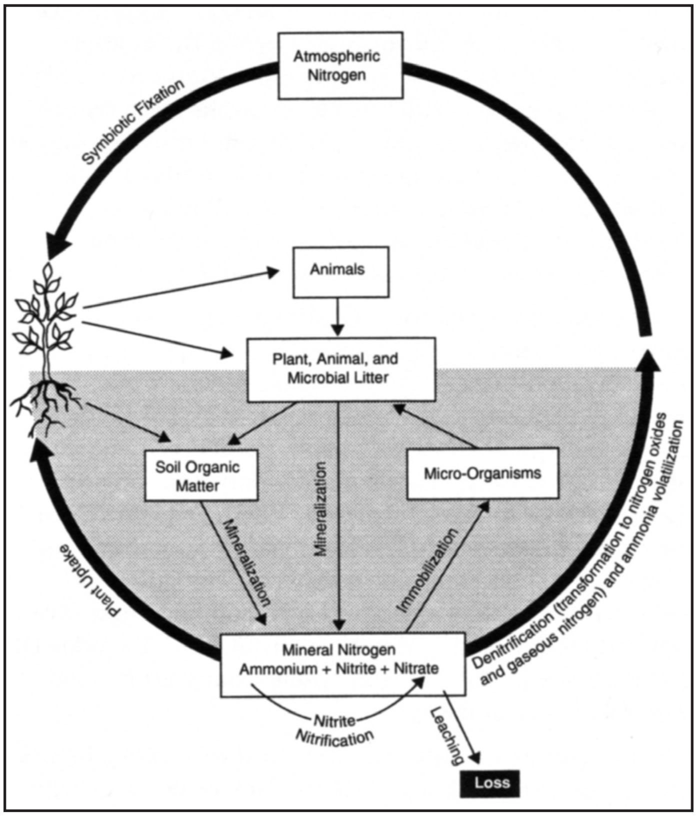
Bacteria, nutrients, and sediment contaminants are typically related to land use activities such as construction, agriculture, or forestry. Toxic chemical contaminant sources may include, but are not limited to, small businesses (such as dry cleaners and gas stations), large businesses (such as factories and refineries), landfills, farms, abandoned industrial sites, military facilities, mines, and septic systems.

Some data contained within this section describe potential sources of contamination that, if left unmanaged or in the event of an accidental release, could have serious impacts on the environment. Other sources exist that are defined as potential sources because the Department does not currently possess information that definitively links a source to observable contamination. These potential sources may be considered possible or suspected sources.

The contaminant assessment that follows describes the various toxic and conventional contamination sources that the Department has identified as existing within Delaware Bay and Estuary Basin. These sources are grouped and presented as source types. As an example, landfills are considered a source type. Therefore, all landfills within the Basin are discussed under one heading. Under each source type, additional information is presented for those individual sources where contamination levels are of concern. Separate maps for chemical and nutrient sources are also presented in this section. Trends and/or data gaps within a source type are also identified.

A database, called the Site Index database [available on

Figure 2.3-1
The Soil-nitrogen cycle



Internet via the "Environmental Navigator" at http://www.dnrec.state.de.us,] has been developed for known and potential contaminant sources within the Basin. This database is designed to be an easy-to-update, central registry of contaminant site-summary data. This database is not intended to replace more detailed program-developed databases, such as the Site Investigation and Restoration Branch's Site Status Database, but rather to be an index to site data stored by the various programs in the Department. This database includes basic site identification information (name, ID number, XY location, basin), site type (e.g., underground storage tanks, spray irrigation sites, etc.), and a contact for more details about the site. Besides this basic information, the database also includes monitoring activity status and contamination potential ratings by media (soil, sediment, surface water, ground water) and contaminant class (nutrients, bacteria, petroleum, organics, pesticides, PCBs, metals and inorganics) for each site. Database contents can be queried and displayed on-line through the database interface. Through the linking of the database with the GIS program Arcview, any number of sites can be plotted on a map. Using this database, it is possible to answer questions such as "Where are all the known PCB contamination sites in the state?" or, "Are there any contaminated sites near a proposed land acquisition area?" Delaware Bay and Estuary Basin site data currently loaded in the database includes:

- Animal Operations;
- Combined Sewer Overflows;
- Dredge Spoils (Confined Disposal Facilities (CDFs));
- Hazardous Waste Generators;
- Landfills & Dumps;
- Large On-site Septic Systems;
- National Pollutant Discharge Elimination System (NPDES) outfalls;
- Pesticide Loading, Mixing and Storage Facilities;
- Salvage Yards;
- Site Investigation and Restoration Branch (SIRB) State and Federal Superfund Sites;
- Sludge Application Fields;
- Spray Irrigation Fields;
- Tire Piles;
- Toxics Release Inventory (TRI) Locations; and
- Underground Storage Tank (UST) Facilities

In addition to these, the Department also has data for dwellings with individual septic systems throughout the Basin and the State (*refer to Map 2.3-1 Septic System Locations*).

2.3.3 NUTRIENTS

Nutrient enrichment of surface waters is a natural process, spanning thousands of years, resulting from natural erosion and the breakdown of organic material. However, activities linked to soil erosion, domestic waste disposal, and runoff can greatly increase the rate and amount of nutrients reaching waterways, accelerating the nutrient enrichment process (DNREC 305(b), 2002). Nitrogen (N) and phosphorus (P) are the major nutrients that cause eutrophication of surface waters. Eutrophication is an increase in the nutrient status of natural waters that causes accelerated growth of algae or water plants, depletion of dissolved oxygen, increased turbidity, and a general degradation of water quality. The enrichment of lakes, ponds, bays and estuaries by N and P from surface runoff or ground-water discharge is known to be a contributing factor to eutrophication. According to the 2002 (305(b)) Watershed Assessment Report, nutrients pose a serious threat to water quality, aquatic life, and human health. Most nutrients are transported to estuaries and lakes by rivers and ground water. Agricultural runoff, urban runoff, and municipal and industrial point source discharges are the primary sources of nutrients.

2.3.3.1 Nitrogen

The soil nitrogen (N) cycle (*Figure 2.3-1*) is a conceptual summary of the interactions among the chemical and biological transformations undergone by N in the soil (Reeder and Sabey, 1987). The key reactions for organic N sources include:

- cycling of N between organic and inorganic forms (mineralization and immobilization);

- gaseous losses (ammonia volatilization and denitrification);
- losses associated with water movement (leaching and erosion);
- symbiotic process of biological N fixation; and
- plant N uptake and subsequent removal in the harvested portion of crops.

Many of these reactions are controlled by soil microorganisms which alter the form, oxidation states, and thus the fate of N, among N_2, N_2O (nitrous oxide), NH_3/NH_4^+ (ammonia/ammonium), NO_2^- (nitrite) and NO_3^- (nitrate). The relative importance of these reactions varies with soil and environmental conditions. Nitrate leaching is a major concern in humid regions (such as Delaware) where excessively well-drained soils overlie shallow water tables (Sims, 1995).

Mineralization

Mineralization refers to the conversion of organic forms of N (proteins, amino sugars and nucleic acids) to ammonium-N (NH_4^+). Heterotrophic soil microorganisms mediate the mineralization process, using the organic N as an energy source for their metabolism. Nitrification is the conversion of the mineralized NH_4^+-N into nitrite (NO_2^-), and then nitrate (NO_3^-) by chemoautotrophic bacteria; these aerobic bacteria obtain their carbon from CO_2 and their energy from the oxidation of NH_4^+ (ammonium). In immobilization, the reverse of the mineralization process, soil microorganisms assimilate inorganic N (NH_3, NH_4^+, NO_2^-, NO_3^-), and transform these mineral forms of N into the organic compounds that are the microbial biomass (Sims, 1995). The balance between the two biological reactions of mineralization and immobilization determines the amount of plant-available inorganic N in the soil matrix.

Environmental factors controlling mineralization, nitrification, and immobilization reactions, as well as the soil itself, must be understood to ensure optimal quantities of available N when organic N sources are used as a fertilizer. As these processes are controlled by soil microorganisms, all parameters that affect biological activity (temperature, moisture, aeration, and soil pH) will influence the rate and extent of these three N transformations (Sims, 1995). "Optimum" conditions for these transformations have been broadly defined and vary slightly between mineralization-immobilization reactions and nitrification. For mineralization, optimum conditions are a temperature range of 104-140°F and soil moisture content of 50-75 percent of soil water-holding capacity. For nitrification, optimum conditions occur when temperatures are 86-95°F, moisture content is 50-75 percent of soil water-holding capacity, and the pH value is between 6.0 and 8.0 (Sims, 1995).

Ammonia Volatilization

Ammonia volatilization refers to the loss of NH_3 from the soil as a gas, and is normally associated with high free NH_3 concentrations in the soil solution and high soil pH. The most successful approach to reduce NH_3-N volatilization from organic wastes has repeatedly been shown to be rapid incorporation with the soil. For example, only 10 percent of the added NH_3-N was lost when poultry manure was incorporated immediately, as compared to a loss of 56 percent when it was incorporated after 3 days (Sims, 1995).

Denitrification

Denitrification is the reduction of NO_3^- to a gaseous form of N, by chemoautotrophic bacteria. As with all microbial reactions, denitrification is influenced by carbon (energy) availability, temperature, aeration/moisture, and soil pH. Amending soils with organic wastes generally increases the potential for denitrification losses of N (providing nitrification of organic N has occurred), because wastes provide available carbon and increase soil moisture-holding capacity.

Nitrogen can also be transported from organic waste-amended soils into ground water by leaching and to surface waters by erosion or runoff. Losses of N by leaching occur mainly as NO_3^- because of the low capacity of most soils to retain anions. In general, any downward movement of water through the soil profile causes leaching of NO_3^-, with the magnitude of loss being proportional to the concentration of NO_3^- in the soil solution and the volume of leaching water (Sims, 1995). Nitrate that leaches below the crop-rooting zone represents loss of a valuable plant nutrient, and hence an economic cost to agriculture. If the nitrate enters ground water, two major environmental problems can occur. The consumption by humans or animals of drinking water with high nitrate levels has been associated with several health problems, the most serious being methemoglobinemia (O_2 deficiency in blood) in infants. Additionally, ground water with high nitrate levels that discharge into sensitive surface waters can contribute to long-term eutrophication of these water bodies. The setting most conducive to NO_3^- (nitrate) leaching and ground-water pollution is a sandy, well-drained soil, with shallow water table, in an area that receives high rainfall and frequently applied fertilizers, manures, or other N source material (Sims, 1995). However, any situation involving over-application of wastes and/or fertilizers, or intensive irrigation, has the potential to cause significant NO_3^- leaching, regardless of soil and climate (Sims, 1995).

According to Johnson (1976), ground water may contribute as much as 80 percent of the total flow in shallowly-incised streams. Ground water also supplies all of the drinking water in Kent and Sussex counties. Chemical fertilizer, manure, and septic system leachate are major sources of ground-water nitrate contamination in Delaware. As evidence, researchers have noted a link between agricultural land activities and elevated ground-water nitrate levels (Ritter and Harris, 1984, 1992; Denver, 1989). Also, intense poultry production has also been associated with elevated nitrate levels (Andres, 1992). Finally, septic tanks have been identified as a localized source of nitrate, especially when numerous systems are concentrated in an area (Denver, 1989). Provided a source of nitrate exists, a more critical factor is soil type and depth to water table (Ritter and Harris, 1984; Andres, 1991; Denver 1989; Bachman, 1984). Even if nitrate sources are extensive, areas with poorly-drained soils do not tend to have high nitrate levels in ground water. Low oxygen conditions in poorly-drained soils allow for greater denitrification so that nitrogen escapes to the atmosphere rather than leaching into ground water.

Erosion

Erosion refers to the transport of soil from a field by water or wind. Surface runoff is the water lost from a field when the rate of precipitation exceeds the infiltration capacity of the soil. Both processes can transport soluble inorganic N and organic N to surface waters and contribute to eutrophication or to drinking-water contamination. Several watershed studies have shown that most of the N lost by erosion or runoff is sediment-bound organic N (Sims, 1995). Although the solubility of NO_3^- favors its loss in runoff as opposed to sediment transport, total N losses from most watershed studies are usually several-fold greater than soluble N.

Surface applications of organic wastes are undesirable because they increase the likelihood of soluble and organic N losses by erosion and runoff. In agricultural operations, conservation practices designed to conserve soil by reducing tillage may involve applying manure to soil surfaces. Surface application of manure also occurs when farmers apply manure during winter months, when the soil is frozen and easily traversed by heavy equipment. The use of grassed waterways or filter strips that trap sediment and accumulate soluble N in plant biomass can help reduce N losses in these situations (Sims, 1995).

2.3.3.2 Phosphorus

Phosphorus (P) is an essential plant nutrient, and vital for the successful production of agronomic crops. It is essential for most physiological processes in plants, such as photosynthesis, energy transfer, genetic regulation of cell division and growth, and the production of seeds and fruit (Sims, 1996). If soils are deficient in P, plants may become stunted, with poorly developed root systems. As a result, significant reductions in yield may occur. Studies show that long-term application of animal wastes to soils increases phosphorus levels well beyond the amount needed for effective crop production (Mozaffari and Sims, 1994). Phosphorus contributes to eutrophication by entering surface waters via erosion (sediment-bound P), runoff (soluble inorganic and organic P), or subsurface flow. Accordingly, accumulated levels of soil P must be reduced, and transport of soluble or sediment-bound P to sensitive water bodies needs to be inhibited.

Bioavailable phosphorus (BAP) (either dissolved or particulate form) in agricultural runoff can promote fresh-water eutrophication (Sharpley and others, 1996). While dissolved phosphorus (DP) is immediately available for uptake by aquatic biota, a variable portion of particulate phosphorus (PP) represents a secondary and long-term source of BAP in lakes (Sharpley, 1993). DP in runoff originates from the release of P from a thin zone of surface soil and vegetative material. Particulate or sediment-bound P is associated with soil and vegetative material eroded during runoff. BAP includes DP and a portion of PP that is in equilibrium with DP and available for algal uptake.

Crop production systems are forced to continually use manure as fertilizer because of the lack of economically viable alternatives for manure disposal. As a result, these systems almost always build soil P levels well beyond ranges considered optimum for most agronomic crops. The unfavorable N:P ratio in most manures results in over-application of manure P relative to crop P needs. Consequently, soil test P has accumulated to levels that are of environmental rather than agronomic concern (Sharpley and others, 1996).

Phosphorus is retained in soils by several mechanisms, collectively referred to as "P fixation." Phosphorus can also be immobilized in an organic form if the C:P ratio of an added organic material is high (normally greater than 300:1). The primary soil constituents involved in P retention are: the hydrous oxides of Iron (Fe) and Aluminum (Al), the alumino-silicate minerals, soil carbonates, and soil organic matter. Amending soils with manures, litters, or other organic wastes has been shown to affect the adsorption-desorption process for P.

In animal wastes, phosphorus is found in both organic and inorganic forms (e.g.>50 percent of phosphorus in poultry litter can occur as inorganic phosphorus) (Goggin and others, 1997). Organic forms of phosphorus are slowly converted to soluble, inorganic forms (Mozaffari and Sims, 1996). In fact, phosphorus from animal waste is probably used by plants as efficiently as that provided in a broadcast, inorganic fertilizer. Most (>70 percent) of the phosphorus in Delaware soils is fixed by aluminum or iron in forms that are only slowly available to plants (Mozaffari and Sims, 1996; Vadas, 1996).

In contrast to nitrogen, phosphorus levels are low in ground water, even in agriculturally-affected ground water (Denver,

$$\frac{(2e^{9}\ \text{fc x 3.3 people per boat) x (0.065 discharge rate)}}{\text{(70 total coliforms per 100 ml) / average depth}}$$

1989). Ground water is not considered a phosphorus-loading pathway. Phosphorus is lost from agricultural fields in either a soluble form dissolved in surface runoff and subsurface, laterally flowing water, or a particulate form bound to eroded soil particles or organic matter. Dissolved phosphorus can either:

- leave a field in surface runoff;
- move through the soil and leave a field in subsurface, laterally flowing water; or
- percolate into the soil where it may eventually leave a field in water drained by tile drains or drainage ditches.

Under low oxygen conditions, iron-bound phosphorus may be released from sediments. Also, organically-bound phosphorus may be released when biota consume organic matter in the sediments. Historic erosion is the likely source of stream and lake-bed sediments which currently may be releasing phosphorus.

2.3.4 BACTERIA (PATHOGEN INDICATORS):

As the name implies, indicator bacteria are indicators of pathogenic (disease causing) bacteria and viruses. Sources of indicator bacteria (enterococcus and coliform) are widespread. Sources of most concern are those of human origin such as raw or inadequately treated sewage. Wildlife and animal operations, such as feedlots, can also be significant sources of indicator bacteria, although they represent less of a risk to human health compared to human wastes (DNREC (305(b)), 2002). High levels of bacteria pose an increased risk of illness to shellfish consumers, swimmers, and others who may come in contact with contaminated waters.

Indicator bacteria are reflective of a concern for a variety of human enteric viruses, various other unclassified viruses, shellfish diseases, and bacterial pathogens.

At present, with regard to indicator organisms, the Total Maximum Daily Load (TMDL) concept has only been applied only to marinas. The TMDL concept is based on theoretical loading, considering all sources, of bacteria that could indicate the presence of disease. The potential daily pathogen output from one person's untreated sewage could be equivalent to treatment plant sewage for hundreds to thousands of people, depending on the level of treatment in the plant. The boat/marina-related TMDL concept assumes zero fecal coliform background water, and establishes buffers around marinas based on the dilution volume required to reach the 70 total coliform per 100 ml standard. The dilution formula includes Delaware-specific loading factors, and is as follows:

In addition, the Shellfish Program also tracks naturally occurring toxic phytoplankton. While the presence of these causative organisms is documented for the Basin, none have occurred at toxic levels.

Of the 275,000 acres of shellfish waters monitored under the Shellfish Program, the majority are in the Delaware Bay Basin. A total of 182,000 acres are Approved for the harvesting of shellfish, and 65,000 acres are classified as Prohibited. All Delaware Bay tributaries are classified as Prohibited, with Prohibited buffers around the mouths of the rivers in the Bay-proper. Additionally, the Delaware River is classified as Prohibited north of the New Castle/Kent line. The Delaware Bay supports Delaware's only oyster harvest. In addition, the near-shore areas of the Bay support a recreational shellfishery, including hard clams (*Mercenaria mercenaria*), soft clams (*Mya arenaria*), and surf clams (*Spisula solidissima*).

2.3.5 CHEMICALS

Chemical contaminant sources located within the Delaware portion of the Delaware Bay and Estuary Basin consist of a variety of contaminants, including heavy metals, solvents and organics, polychlorinated biphenyls (PCBs), pesticides and herbicides, and petroleum. Chemical contamination may adversely impact human health or the environment through various toxic effects that different chemicals pose.

Chemical contaminants have been grouped into six classes:

- heavy metals;
- solvents and other organic compounds;
- PCBs;
- pesticides and herbicides;
- petroleum; and
- other inorganic compounds

Heavy Metals include iron, arsenic, cadmium, chromium, manganese, nickel, lead, barium, and zinc. Some metals are carcinogenic or poisonous to humans and/or other organisms. In high concentrations, metals such as iron or manganese can render water unsuitable for drinking due to taste and staining, even though they might not cause specific health problems.

Solvents and Other Organic Compounds include organic chemicals such as chlorinated solvents, degreasers, paint thinners, alcohols, and certain chemical feedstocks. Many of these chemicals are carcinogenic or poisonous to humans and/or other organisms.

PCBs are a class of organic compounds formerly used in electrical transformers and switches. These compounds are generally insoluble in water and break down very slowly under normal environmental conditions. They can accumulate in stream sediments where they can be directly or indirectly ingested by fish. Most forms of PCBs are considered carcinogenic.

Pesticides and Herbicides are carcinogenic and/or poisonous to humans and other organisms. Many pesticides or herbicides have the potential of being biologically concentrated in the highest part of the food chain.

Petroleum includes, but is not limited to, gasoline, heating oil, diesel fuel, kerosene, and waste oil. Certain compounds contained within each product, such as benzene, are carcinogenic or poisonous to humans and/or other organisms.

Other Inorganic Compounds include chemicals such as chlorides, sulfates, and Total Dissolved Solids (TDS).

Contaminant sources located within the Delaware Bay and Estuary Basin containing the above chemical groups are discussed in more detail under the different source types discussed below. Source locations are provided on *Map 2.3 2 Known and Potential Nutrient Sources, Map 2.3-3 Know and Potential Chemical Sources,* and *Map 2.3-4 Known and Potential Chemical Sources – City Details*. Specific chemicals may be identified from a contamination source where specific information on such contamination exists.

2.3.6 INVENTORY OF POTENTIAL NUTRIENT SOURCES

2.3.6.1 Agriculture

The land area of the Delaware Bay and Estuary Basin is comprised of 520,960 total acres, with roughly 44% of this acreage used for agriculture. Agriculture is Delaware's number one industry, with poultry the primary agricultural product and largest animal based industry in the State.

Sussex County is the number one broiler-producing county in the nation, with over 262 million broilers/roasters grown in 1995 (Delaware Department of Agriculture, 1996).

The dairy industry is the second largest animal-based waste generator in Delaware (Goggin and others, 1997). Delaware Department of Agriculture records indicated approximately 100 registered dairy farms in Delaware. Overall, dairy farms are not increasing in numbers, although production reports indicate steady increases in total milk production by farm, as well as milk produced per cow.

Delaware's swine industry is currently undergoing major changes. Delmarva is experiencing the arrival of integrated swine operations, similar to those seen in the poultry industry,

TABLE 2.3-1
ESTIMATED AGRICULTURAL NUTRIENT BUDGET FOR DELAWARE

Nutrient Contribution By Source	Tons Nitrogen/yr (% Of Total)	Tons Phosphorus/yr (% Of Total)
Chemical Fertilizer	22,127 (66%)	7,858 (59%)
Poultry	8,651 (25%)	3,845 (29%)
Cattle	2,175 (7%)	1,215 (9%)
Swine	365 (1%)	285 (2%)
Sludge	183 (0.5%)	110 (1%)
Wastewater	3 (-)	< 0.1 (%)
Total Nutrient	**33,504**	**13,313**
Nutrients Required	**18,216**	**3,234**
Nutrient Excess	**15,288**	**10,079**

References:
1. *Delaware Agricultural Statistics Summary, 1992*
2. *Livestock Waste Facilities Handbook, 1985*
3. *Sims, J.T., Wolf, D.C., 1994*
4. *Ron Graeber, personal communications*
5. *Richard Barczewski, personal communications*
6. *Doris Hamilton, personal communications*

and contract-growing systems in Delaware are possible in the future. While producer-numbers may decrease in Delaware, Delmarva may actually experience a net gain in the number of sows located in the region as the larger farms become more prevalent. Operating conditions in Delaware vary widely, with some hogs raised on dirt lots, and others raised in total confinement (Goggin and others, 1997).

Environmental impact of dairy, swine, and beef manure may be of concern on a site-specific basis, but is of relatively less concern than the impact from poultry (DNREC, 1995). Dairy operations exist throughout the state. Beef cattle operations exist throughout the state but the number of operations increases to the south. The swine industry is mostly in Sussex County, aggravating the existing problem of excessive nutrients in the county.

Water quality sampling and research from demonstration projects throughout Delaware indicate a strong need for concern about the fate and impact of nitrogen, phosphorus, and bacteria on surface and ground waters from agricultural sources. According to the Delaware Guidelines for Animal Agriculture (Goggin and others, 1997), manure can be a valuable agricultural by-product if managed properly. Manure contains three major plant nutrients - nitrogen, phosphorus and potassium, as well as essential elements like calcium, sulfur, boron, magnesium, manganese, copper and zinc. Applying manure to fields provides valuable plant nutrients, improves soil tilth, aeration, and water-holding capacity, decreases soil erosion potential, and promotes the growth of beneficial soil organisms. Many manure application systems fail to fully utilize these nutrients. For example, applying manure in excess, or at the wrong time, or improperly handling it, may release nutrients into the air or water. Instead of only providing nourishment to the crops, the nutrients also become pollutants.

The major concern is that excess nitrogen may leach through the soil and into the ground water. Accordingly, nutrient management in areas dominated by animal-based agriculture is a major nonpoint source pollution issue. The Delaware Nonpoint Source Management Plan (DNREC, 1995) calculated a statewide nutrient budget (*Table 2.3-1*) showing nutrient excess of 15,288 tons of nitrogen/year and 10,079 tons of phosphorus/year. According to DNREC (1995), chemical fertilizers alone are applied at rates greater than the calculated crop acreage requirements. When combined with chemical excesses, organic fertilizers, especially manures, become part of the overall problem. DNREC (1995) suggests that chemical fertilizers are more evenly distributed throughout the state and are less of a concern than manures because the manures are not evenly distributed. Manure does not lend itself to inexpensive, easy transport due to its bulk, and thus has a tendency to be land applied in close proximity to the animal operation. The animal production industry, in particular the poultry industry, is not spread out, but rather, is concentrated in specific areas. Transport of manures away from these areas is limited, and cost prohibitive if transport distance is greater than fifteen miles (DNREC, 1995).

Another management conflict arises when considering the N and P ratio in poultry manure. Applying poultry manure at rates that meet crop nitrogen requirements results in over-application of phosphorus. Land application of animal waste can add more P to soils than is removed in harvested crops, resulting in a long term accumulation of soil P (Sims, 1997). Phosphorus buildup in Delaware soils has been documented by the University of Delaware's Soil Testing Laboratory (Cooperative Bulletin No. 45, 1993). A summary of thirty-seven years of soil data at the Laboratory shows that soil phosphorus levels have been steadily increasing in many areas. In 1994, 72 percent of all commercial crop soil samples received had a "high" or "excessive" level of plant available phosphorus (no phosphorus fertilizer recommended). Twenty percent of all commercial crop soil samples from Sussex County had double the optimal level of phosphorus. Previous research in other mid-Atlantic states indicates that it can take from 10 to 20 years, with no additional application of P, for normal cropping practices to deplete soil P from excessive to optimum levels (McCollum, 1991).

The University of Delaware does not recommend P application for fields that have high or excessive levels of plant available phosphorus. At most, a minor starter application of P in the spring is recommended because soils do not release phosphorus fast enough for seedlings in the spring (DNREC, 1995). In addition, Sims (1995) notes that roughly one-half of the 290,000 acres of non-pasture cropland in Sussex County are in soybeans. Soybean production requires no nitrogen fertilizer and often only starter amounts of phosphorus. Sims (1995) suggests that, provided manure is not applied to soybean fields, poultry manure alone could meet all crop nutrient needs in Sussex County. DNREC (1995) suggests that any solution to phosphorus surface water contamination must reconcile excessive phosphorus delivery with farmers' concerns for adequate crop fertilization.

Areas with high densities of animal production are prone to excess nutrient accumulation resulting in ground and surface water pollution.

Water quality impacts and nutrient loadings to surface waters depend on management practices. Reports commissioned by the Center for the Inland Bays provide values for nutrient loadings to surface waters from agricultural land. University of Delaware researchers have completed studies of agricultural practices, manure nutrient content, and other nutrient management issues.

Accurate values do not exist for nutrient loading reduction resulting from implementation of best management practices. The Natural Resources Conservation Service does have values that are used for national reporting but those values should be used cautiously, considering the meaning of those values. A number of management, weather, and geographic variables can dramatically affect values. Also, evaluating individual management practices may not accurately portray overall reductions. For instance, storing manure in a shed is important to reducing nutrient pollution and some loading reduction estimates have been developed. However, if the stored manure is then improperly applied to the land, no pollution reductions have actually occurred. Storage, by itself, does not remove nutrients; it simply prevents the transport. Improper land application then allows that transport to occur. *Table 2.3-2* summarizes efforts and directions of management practices on the farm.

Regional Nutrient Removal and Handling Efforts

Approximately 750,000 tons of manure are generated on the Delmarva Peninsula each year. In addition to ensuring good environmental practices on individual farms, regional excesses of manure require a comprehensive regional management strategy. The current status of existing options is discussed in this section.

Transport

The cost to transport manure within a 15-mile radius of generation is about $15 - $20 per ton.

Pelletization

Perdue AgriRecycle has put into operation a pelletization plant in the Laurel. Plant construction was subsidized with $1 million in state funds, and a $12 million low interest loan. The plant is capable of processing approximately 90,000 tons of manure each year. The product is being used as an organic fertilizer and sold to local fertilizer dealers, existing accounts in the Midwest, and planned expansions into the southeast and northeast. The plant in Seaford is unable to utilize manure generated in the Delaware Basin since plant capacity is being met by more local sources.

Composting

Composting facilities are available in Maryland for regional use. The most active facility processes 5,000 tons of manure per year. Development of product marketing has been subsidized with federal grant funds through Delaware's Nonpoint Source Program. A site is currently under construction in Delaware near Milton and will potentially process 10 – 20 tons of manure per year.

Waste to Energy

Allen's Family Foods intends to install a unit that generates 3.9 megawatts of energy from a litter gasification recovery system. Half of the electricity will be used to power Allen's processing plant and the rest will be sold to a local power grid. Allen's will supply half of the manure required and the other half will be from local growers.

Table 2.3-2 On-Farm Best Management Practice (BMP) options

Best Management Practices (BMP)	Total Acres/Facilities Existing	Number of BMP's Installed or Acres planned to Date
Nutrient Management Plans	72,246 acres of agricultural land	36,068 acres with nutrient management plans (not including plans by private contractors)
Animal Waste Systems	Dairy: 2 facilities Hog: 9 facilities Beef: none	Dairy: 2 systems Hog: 7 systems Beef: none
Manure Storage Structures	Total number of poultry operations = 239 (each operation may have more than one storage structure)	Number of structures built = 108 Number of structures planned = 53
Dead Bird Composters	Total number of poultry operations = 239 (each operation may have more than one structure)	Number of structures built = 97 Number of structures planned = 33
Fencing		Installed = 1,308 ft
Filter strips		Installed = 132 acres Planned = 692 acres
Grassed waterways		Installed = 2.9 acres Planned = 1 acre
Stream buffers (tree/shrub)		Installed = 166 acres Planned = 423 acres
PSNT Tests	Average number of acres planted in corn = 23,000-24,000 approx.	Total number of tests = 79 Total number of acres = 4,163 (these numbers are for 1999 only)
Soil Testing		
Manure analysis	Total number of producers = 239	
Conservation tillage	Total acres of agricultural land = 72,246	Total number of acres planned = 13,325
Cover crop		Total number of acres planned = 15,500
Water Control Structures	Number of structures installed = 42 Structures planned = 7	
Manure Spreader Calibration	About 5 request/yr.	Should be 1 time/yr. per land owner

Incinerator projects for generating electricity from burning manure have been proposed for Sussex County. A recent law banning incinerators would have to be amended to allow a waste-to-energy incinerator to be built. State agencies are pursuing that amendment.

2.3.6.2 Non-agricultural Nutrient Use

In urban areas, activities such as the maintenance of residential and commercial lawns, golf courses, and parklands, use nutrients in ways that may adversely impact the waterways (*refer to Table 2.3-3*). Urban land uses comprise 17% of the Delaware Bay and Estuary Basin's land area. Little data have been collected regarding nutrient loading from urban turf acreage.

While proper management of turf should be pursued, the management of urban landscapes is likely to result in minor nutrient loading reductions since they cause a much smaller portion of nutrient loading than other sources.

Transport of applied nutrients from turf is likely to be less than from row-crop acreage. Turf covers the ground year-round and typically covers the surface comprehensively. Therefore, nutrient uptake can occur for a greater period of time with less erosion and less runoff than for row-crop acreage.

Direct transport of nutrients from urban landscapes occurs where fertilizers fall onto adjacent impervious surfaces and wash into storm drains or into adjacent surface waters.

Home Owners

There is more land under care of homeowners than golf courses. Homeowners have little training or knowledge of nutrient application. Public information and education appear to be moderate where fertilizers are applied.

Professional lawn care services

Professional lawn-care services affect more turf acres than all homeowners. They appear to be working within standard recommended application rates. Staffs are required to take pesticide training regularly.

Golf Courses

For golf courses and athletic fields, improperly located mixing pads facilitate nutrient transport. Surveys conducted in Delaware, as reported by superintendents, suggest that overflow from runoff/irrigation ponds could enter wetlands on 21% of golf courses and enter surface waters on 37% of golf courses. Runoff from mixing/wash pads is allowed to reach wetlands or natural surface waters on 4% of golf courses; 33% of golf courses have active play areas adjacent to surface water bodies; 65% of those courses reports having vegetative buffers along the interface.

Loading reductions are best captured through environmentally-sound design and construction methods. Delaware golf-course superintendents have, on average, strong educational backgrounds; 92% have specialized post-high school education in turf management. Forty-two percent of Delaware golf courses were actively involved in Audubon Cooperative Sanctuary Program for Golf Courses.

2.3.6.3 Mixing, Loading and Storage Areas for Pesticides and Fertilizers

These sites serve as areas to store, mix, and load pesticide products and/or liquid and solid fertilizer products. Products are generally stored in large bulk quantities. Products may be stored in individual packages in a warehouse, or in large mixing tanks, drums, or mini-bulk containers.

The potential exists for a product to be released during mixing or loading of the product onto transporter vehicles or application equipment. The potential also exists for storage container failure. While some sites have modern containment systems, including dikes, berms, and product recovery systems, many do not.

Currently, the design of these facilities is not regulated, and no monitoring data exist for these sites. However, the U.S. EPA is developing draft regulations that address this shortcoming. Refer to *Map 2.3-2 Known and Potential Nutrient Sources* for the location of known sites.

2.3.6.4 On-Site Septic Systems

Septic systems are the main method for treatment of domestic wastewater used in the rural or unsewered areas of the Delaware Bay and Estuary Basin (*refer to Map 2.3-1 Septic System Locations*). In portions of unsewered sections, especially rural homesteads and older subdivisions, cesspools are still in use. Most are undocumented. A cesspool is usually a large, open-bottomed tank, which drains both liquid and solid wastes directly underground. A septic system is a more engineered waste disposal system compared to a cesspool, and is usually comprised of a septic tank for solids, and a distribution box and drainage field for liquids. The drainage field may be either gravity or pump fed.

Although domestic wastewater can contain a wide range of substances, its chemical composition is relatively simple compared to municipal wastewater, which obtains liquid wastes from a variety of sources including housing, commercial, and industrial activities. Potential contaminants in domestic wastewater include: dissolved organic matter, heavy metals, biological oxygen demand (BOD), pathogenic microorganisms, and soil nutrients such as nitrogen and phosphorus.

TABLE 2.3-3 NON-AGRICULTURAL FERTILIZER USE IN DELAWARE

<table>
<tr><th rowspan="3"></th><th rowspan="3">Total Delaware Acreage</th><th colspan="4">Fertilizer Application Rates (lbs./1000 ft²/yr)</th></tr>
<tr><th colspan="2">Typical</th><th colspan="2">Recommended[2]</th></tr>
<tr><th>Nitrogen</th><th>Phosphorus</th><th>Nitrogen</th><th>Phosphorus</th></tr>
<tr><td>Home Owners[3]</td><td>72,485</td><td>2.4</td><td>0.3</td><td rowspan="11">2 to 4</td><td rowspan="11">0.4 to 1.4</td></tr>
<tr><td>Professional Lawn Care Services[4]</td><td>8,628</td><td>1.0</td><td>0.2</td></tr>
<tr><td>Athletic Fields[5]</td><td>145</td><td></td><td></td></tr>
<tr><td>Golf Courses</td><td>3,762</td><td></td><td></td></tr>
<tr><td>Greens</td><td>290</td><td>0.125 to 1.0</td><td></td></tr>
<tr><td>Tees</td><td rowspan="2"></td><td>0.16 to 1.0</td><td></td></tr>
<tr><td>Fairways</td><td>0.33 to 1.0</td><td></td></tr>
<tr><td>Roughs</td><td></td><td>≤1.0</td><td></td></tr>
<tr><td>State Parks</td><td>18,976</td><td></td><td></td></tr>
<tr><td>Fertilized</td><td>26</td><td>2.3</td><td>0.2</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td>Commercial & Industrial</td><td>59,356</td><td colspan="4">(mostly impervious surfaces)</td></tr>
<tr><td colspan="6">[1] Jenny McDermott, personnel communications</td></tr>
<tr><td colspan="6">[2] University of Delaware recommendations for typical application rates.</td></tr>
<tr><td colspan="6">[3] Typical application rates for homeowners fertilizing their own lawns</td></tr>
<tr><td colspan="6">[4] Estimated total turf managed by all known landscapers (with Pesticide Applicator Licenses) and may include residential, commercial, athletic fields.</td></tr>
<tr><td colspan="6">[5] Athletic fields statewide range from 1.5 to 25 acres. Sixty percent use professional landscapers.</td></tr>
</table>

New Castle, Kent, and Sussex Counties, and municipalities have governing authority over sewered areas and their locations.

In the 1998, the Center for the Inland Bays funded a septic mapping project. The project used the 1992 and 1997 aerial GIS photos to identify any house located outside a sewer district. The information represented in *Table 2.3-4* assumes that any house outside a sewer district has an onsite septic system. However, large septic systems, community septic systems, commercial septic systems, and spray irrigation facilities serve some of the houses that are assumed to have on-site septic systems.

Installing a septic system in Delaware involves three steps. The first step requires a site evaluation. Site evaluations consist of investigating, evaluating, and reporting basic soil and site conditions. Each report describes specific site conditions or limitations including, but not limited to: isolation and separation distances, slopes, existing wells, cuts and fills, and unstable landforms. Each report also contains information about zoning verification; the type of onsite disposal system that must be constructed in the acceptable onsite disposal area; the results of the hydraulic conductivity test conducted; easements; and underground and overhead utilities in the evaluated area. This siting procedure ensures that septic systems are properly located using the following soil properties: permeability, texture, structure, consistency, redoximorphic features, slope, and depth to rock.

The second step requires hiring a licensed system designer to design the septic system required by the approved site evaluation and obtaining design approval by the Ground Water Discharges Section. The final step after the permit is approved involves hiring a licensed system contractor to construct the system under supervision of the Section.

In spite of this permitting process, there are approximately eighty septic system complaints filed with the Department on a yearly basis statewide in regards to malfunctioning on-site septic systems. On average, during a given year, the Department issues 2,200 on-site septic permits per year. Approximately 25 percent of these permits are for replacing existing disposal systems or components, with the remaining 75 percent of the sep-

TABLE 2.3-4 ON-SITE SEPTIC SYSTEMS

Project	Number of Systems
1992 Mapping	26,371
Systems added between 1992 and 1997	6,009
Systems removed between 1992 and 1997	70
1997 Mapping	32,310

tic permits issued for new home construction on individual lots.

2.3.6.5 Large On-site Community Disposal Systems

Large community septic systems are on-site wastewater disposal systems which serve more than one lot or parcel or more than one dwelling unit of a planned development or industrial use. The projected daily wastewater flow in these types of systems is greater than 2,500 gallons. A large community system is a more complex waste disposal system, usually comprised of holding tanks for solids, and a pressure dosed distribution system. Similar to domestic wastewater from smaller on-site septic systems, community systems contain a wide range of substances: dissolved organic matter, heavy metals, pathogenic microorganisms, and nutrients such as nitrogen and phosphorus.

In the Delaware Bay and Estuary Basin, there are 25 permitted large onsite wastewater treatment and disposal systems. These systems are regulated under The Regulations Governing the Design, Installation, and Operation of On-site Wastewater Treatment and Disposal Systems. All projects with estimated flows exceeding 2,500 gpd must be accompanied by a preliminary ground-water assessment, which is then reviewed by the Department's Ground Water Protection Branch. Eighty-five percent of the large on-site community systems fall under the State's criteria for requiring a site to have a licensed operator to maintain the system to ensure proper maintenance and operation. Seventy-seven percent of the large community system owners are required to monitor ground water on the project site for the following parameters: Depth to Water Table, Temperature, pH, Specific Conductance, Total Nitrogen, Ammonia as Nitrogen, Nitrate (NO_3) as Nitrogen, Coliform Bacteria (Total & Fecal), and Total Dissolved Solids. These monitoring parameters enable the Department to detect contaminants entering the ground water from on-site disposal systems. Such monitoring also helps the Department to discover/prevent ground water contamination from crossing the property boundary of the site.

2.3.6.6 Land Application of Wastes

Land application of wastewater, biosolids, and other residual wastes in a soil system is a viable alternative for the treatment, disposal, and beneficial reuse of municipal and some industrial wastes. Land treatment of wastewater and other wastes provides one of the most environmentally-sound methods of managing wastewater and other residuals. Wastes in the water are taken up by selected plants, fixed in soluble forms in the soil, evolve as gases, or leach into the ground water. Land application provides ground-water recharge and enables governmental agencies to create incentives to maintain farmland or green spaces. The basic criteria for land treatment are:

- quality standards for ground water and surface waters are not exceeded;
- land application of wastes does not present a significant health problem; and
- soil is not degraded so as to prevent future use for agriculture, forestry, or other planned development.

Current land treatment facilities are designed for a 25 to 50-year site life based on wastewater flow, nutrient loading, and metal loading. During the operation of systems, nutrient and metal content of the wastewater is monitored yearly to track the actual site life of these facilities over the long term. Generally, long-term effects of land treatment have shown decreased nutrient loading (compared with conventional farming fertilization practices); nutrient (nitrate) reduction in ground-water recharges; stream discharge decreases due to required conservation planning; and agricultural lands preservation.

In the Delaware Bay and Estuary Basin, there are seven spray irrigation land treatment facilities (*refer to Map 2.3-2*), ranging from food processing and textile finishing to domestic wastewater treatment and disposal. *Table 2.3-5* provides summary information for these facilities.

All permitted land treatment systems undergo a comprehensive design review process. The review covers soil and hydrologic investigative work, and treatment and waste loading calculations. After the permit review process is completed, land-treatment systems are constructed based on plans and specifications submitted to the Department, and done so under the supervision of licensed operators. These licensed operators, in turn, properly operate and maintain the systems. Two of the seven permitted spray irrigation facilities in the Delaware Bay and Estuary Basin have ceased operations. The other five facilities continue to monitor the ground water for the following parameters: Depth to Water Table, Temperature, pH, Specific Conductance, Total Nitrogen, Ammonia as Nitrogen, Nitrate as Nitrogen, Phosphorus, Sodium, Chloride, Total Dissolved Solids and Coliform Bacteria. These monitoring requirements enable the Department to detect contaminants entering the ground water from the land treatment systems. This will also help the Department prevent ground water contamination from crossing adjacent property boundaries of the site. There are seven permitted biosolid land application sites in the Delaware Bay and Estuary Basin, two of which have ceased operations (*refer to Table 2.3-6*).

Table 2.3-5 1999 Nutrient Loadings For Land Treatment Facilities

Facility Name	Acreage Available	Crops Grown	Annual Flow (MGY)	Total Nitrogen Applied (lbs/acre/yr)	Total Phosphorus Applied (lbs/acre/yr)
Summit Farms	13	Fescue / Orchard Grass	15.8	197	20.3
Frog Hollow[1]	113	Golf Course Grasses	N/A	N/A	N/A
M.O.T.	75	Reed Canary Grass	153.6	216	15.7
Hanover Foods	185	Reed Canary Grass/Corn/Soybean	149	204	73
Cedar Village MHP	8	Fescue / Orchard Grass	3.68	62.5	15
Clifton Canning[2]	N/A	N/A	N/A	N/A	N/A
Draper Canning[3]	N/A	N/A	N/A	N/A	N/A

[1] *Construction completed December 1999. No vegetation in 1999.*

[2] *Closed operations in January 1993.*

[3] *Closed operations in February 1996.*

2.3.6.7 Municipal and Industrial Discharges of Wastewater and Storm Water

Both state and federal laws and regulations prohibit any discharge of a pollutant from a point source to state waters, unless sanctioned by a permit. Such permits are issued and administered under the National Pollutant Discharge Elimination System (NPDES). The fundamental goal of the NPDES permit is to eliminate discharge of pollutants from point sources to surface waters.

A point source is generally a pipe, ditch, channel, or other discrete conveyance from which wastewater is discharged. Point-source discharges can be linked to a specific source and location. They typically include discharges from municipal wastewater treatment plants and industrial facilities. Discharges of urban runoff, stormwater associated with industrial activities, cooling water, and combined sewer overflows (CSOs) may also be regulated as "point source discharges of pollutants." NPDES permits can also regulate effects of industrial water intakes, which can impinge aquatic life on intake screens, or entrain smaller organisms in the water flow through the industrial process.

The health of a water body is measured by its attainment of designated uses. A NPDES permit legally sanctions the discharge of substances that may be considered pollutants. For example, a freshwater stream could have designated uses of "protection of aquatic life" and (human) "drinking water." A chloride discharge to that stream is likely a pollutant since it could harm freshwater organisms and drinking water quality. The same chloride discharge is likely not a pollutant when discharged into a saltwater body. Saltwater organisms are accustomed to chlorides and the water body is not used for human drinking water. If potential pollutants in an NPDES discharge are reduced to levels that allow receiving waters to meet designated uses, then the "pollutant" discharge has been eliminated.

The Surface Water Discharges Section (SWDS) within the Division of Water Resources administers the NPDES program in Delaware. *Table 2.3-7* lists individual NPDES permits in the Basin. Whenever the Division makes a tentative determination on an NPDES permits, the Department advertises the proposal in the newspapers for a 30-day "public notice" period. The public notice gives the public opportunity to comment on the proposal, request a public hearing, and have a voice in reaching a final decision.

Delaware also has an NPDES General Permit that governs storm-water discharges associated with industrial activity. Instead of applying to an individual facility, one general permit covers many sites with similar activities. For example, Recycling Centers and Land Disturbing Activities are two of eleven categories covered by the General Permit. This General Permit requires prevention and containment practices to minimize pollutants on industrial sites from being carried into waterways via storm-water runoff.

Each NPDES permit includes requirements for the discharger to collect representative samples of the discharge, analyze specified parameters, and report the results. So the discharger generates and reports the information needed to demonstrate that the discharge meets the objectives of the permit. The SWDS staff review the data submitted, conduct additional surveillance and monitoring of permittees, and provide both assistance and oversight to ensure facilities maintain or regain compliance.

Monitoring can be fairly simple for wastewater discharges such as single-pass noncontact cooling water, for example, where river water is used to cool down metal surfaces but never comes into direct contact with process chemicals. Such discharges may monitor only flow, pH, temperature, and total heat passed into the water from the facility. More complex discharges, such as manufacturers of organic chemicals, may be

TABLE 2.3-6 1999 BIOSOLID LAND APPLICATION SITES

Facility Name	Acreage Available	Crops Grown	Annual Flow (MGY)	Total Nitrogen Applied (lbs/acre/year)	Total Phosphorus Applied (lbs/acre/yr)
Summit Farms	13	Fescue / Orchard Grass	15.8	197	20.3
Frog Hollow[1]	113	Golf Course Grasses	N/A	N/A	N/A
M.O.T.	75	Reed Canary Grass	153.6	216	15.7
Hanover Foods	185	Reed Canary Grass/Corn / Soybean	149	204	73
Cedar Village MHP	8	Fescue / Orchard Grass	3.68	62.5	15
Clifton Canning[2]	N/A	N/A	N/A	N/A	N/A
Draper Canning[3]	N/A	N/A	N/A	N/A	N/A

[1] *Construction completed December 1999. No vegetation in 1999.*
[2] *Closed operations in January 1993.*
[3] *Closed operations in February 1996.*

monitored for more than seventy different parameters. Lastly, some facilities do biomonitoring in which aquatic organisms, usually minnows and water fleas, are placed in the wastewater for 24 to 96 hours. Acute biomonitoring checks only that the test organisms survive. Chronic biomonitoring checks survival, growth, and reproduction of the test organisms for adverse effects from the wastewater. *Table 2.3-7* indicates which facilities do acute or chronic biomonitoring.

Historically, Delaware NPDES permits have considered only the effects of the individual permittee's wastewater in determining safe levels for discharging potential pollutants. This approach has been fairly successful in eliminating impairment of designated uses that were caused by single point sources. Delaware NPDES permits are currently evolving to the next phase of considering the effects of all related discharges, via the Total Maximum Daily Load (TMDL) process. The TMDL establishes the total pollutant load a water body can handle, and still meet all designated uses. The total load includes the individual permittee's point-source discharges, but also all other point sources, nonpoint sources (e.g., fertilizer runoff), atmospheric deposition, and ground-water transport.

Table 2.3-8 lists individual permits in the Basin that have been voided in the last ten years. In most cases, discharges to surface waters have been eliminated either by process changes or by redirecting the discharge to a publicly-owned wastewater treatment plant. For two sites, Army Creek Landfill and Healthways, discharges are covered by Superfund regulatory programs, rather than NPDES. Except for Superfund sites, former individual industrial permittees usually retain some NPDES permit coverage under the General Permit for stormwater runoff from their sites, even if the site has shut down.

2.3.6.8 Landfills

Decomposition of organic waste such as household garbage or food processing by-products disposed of in landfills and dumps can be a source of unwanted nutrients to ground water and surface water. The decomposition process in landfills produces soluble nitrogen-rich decay products such as ammonia, nitrate, and complex organic compounds. Rainwater seeping through the waste transports these soluble nitrogen-rich compounds into ground water that ultimately discharges into streams. To produce significant quantities of nutrients, a landfill must contain large quantities of organic waste.

To be considered a potential nutrient source for the purposes of this assessment, a landfill or dump has to be at least five acres in size and contain household garbage or food processing by-products. A number of landfills in the Delaware Bay and Estuary Basin meet these criteria. These landfills receive all municipal waste generated in Delaware and are regulated by the Department's Solid Waste Management Branch. There are four closed landfills under the jurisdiction of the Site Investigation and Restoration Branch of the Department. Routine groundwater and surface-water monitoring of these sites indicates there have been no significant nutrient releases to date.

2.3.6.9 Toxics Release Inventory (TRI) Facilities

Manufacturing facilities report under the Toxics Release Inventory (TRI) on any reportable toxic chemical that is manufactured, processed, or otherwise used above certain thresholds. As of 2001, the reportable list includes 582 individual chemicals and 30 chemical categories. Reports contain data on releases of the specific chemical to air, water, and land, as well as information on chemical in wastes transported off-site or managed on-site. Some of these chemicals, when released into the environment may contribute to nutrient contamination of surface and/or ground water.

Table 2.3-7 NPDES Individual Permits for Industrial and Municipal Sites

Permit No.	Company	Major/ Minor	Ind./ Munic.	Bio-Monitor-ing[1]	Sub-Basin[2]	River[2]	Discharge Description
DE 0000299	Allen Family Foods, Inc.	Major	Ind.	C	Broadkill River	Beaverdam Creek	Process Water
DE 0051047	Baltimore Air Coil	Minor	Ind.		Mispillion River	Haven Lake	CW & Stormwater
DE 0000060	Barcroft Co.	Minor	Ind.				Cooling Water
DE 0050075	Canterbury Crossing	Minor	Mun.		Murderkill River	Double Run Br.	Small STP
DE 0050636	Chloramone Corp.	Minor	Ind.	A	Red Lion Creek		Process Water
DE 0021555	Delaware City STP	Minor	Mun.				STP
DE 0050601	DP&L Delaware City	Major	Ind.			Motiva Sluiceway	Cooling water
DE 0000612	Formosa Plastics Corp.	Major	Ind.	A		Motiva Sluiceway	Process Water
DE 0051063	Hanover Foods	Minor	Ind.		Smyrna River	Providence Creek	Small STP
DE 0020036	Harrington STP	Minor	Mun.		Murderkill River	Brown's Branch	STP
DE 0051080	Uniqema & Avecia, Inc.	Minor	Ind.	A	Magazine Ditch & De. River.		Cooling water
DE 0000647	Kaneka Delaware	Major	Ind.	A			Process water
DE 0020338	Kent County STP	Major	Mun.	C	Murderkill River		STP
DE 0050083	Lums Pond State Park	Minor	Mun.		Ches. & De. Canal		Small STP
DE 0050466	McKee Run	Minor	Ind.	C	St. Jones River	McKee Run	Cooling Water
DE 0020001	Metachem	Major	Ind.	A			Process Water
DE 0050547	Middletown-Odessa-Townsends	Minor	Mun.	C	Appoquinimink River.		STP
DE 0021491	Milton STP	Minor	Mun.	A	Broadkill River		Small STP
DE 0000256	Motiva	Major	Ind.	A		Motiva Sluiceway	Cooling & Process
DE 0050911	Occidental	Major	Ind.	A			Process water
DE 0000469	Perdue, Georgetown	Major	Ind.	C	Broadkill River	Ingram Branch	Process water
DE 0000701	Playtex Family Pdts. Corp.	Minor	Ind.	C	St. Jones River		Cooling Water
DE 0021539	Port Penn STP	Minor	Mun.				Small STP
DE 0000485	Printpack, Inc.	Minor	Ind.				Cooling Water
DE 0000591	Reichhold	Minor	Ind.		St. Jones River	Fork Branch	Cooling Water
DE 0000141	SAW	Minor	Ind.		Broadkill River	Pepper Ditch	001=proc., 002=cw
DE 0051098	Sea Watch	Minor	Ind.		Mispillion River		Process Water
DE 0050172	Southwood Acres MHP	Minor	Mun.		Murderkill River	Double Run	Small STP
DE 0000621	SPI Polyols, Inc.	Major	Ind.			Magazine Ditch	Cooling Water
DE 0051039	VPI Mirrex	Minor	Ind.			Motiva Sluiceway	Process Water

[1] *Indicates which facilities do acute ("A") or chronic ("C") biomonitoring.*

[2] *"Sub-basin" and "River" are blank if discharge is directly to the Delaware River*

Table 2.3-8 Voided Individual NPDES Permits for Industrial and Municipal Sites

Permit No.	Company	Major/ Minor	Ind./ Munic.	Bio-moni-toring[1]	Sub-Basin[1]	River[1]	Discharge Description
DE 0000272	Akzo Chemicals, Inc.	Minor	Ind.	A			Site Shut Down
DE 0050741	Army Creek Landfill	Major	Mun.	C		Army Creek	Superfund Jurisdiction
DE 0050415	Atlantis Plastic Corp.	Minor	Ind.		Broadkill River	Waples Branch	Eliminated Discharge
DE 0050644	DuPont Cherry Island	Minor	Ind.				Eliminated Discharge
DE 0051055	Healthways	Minor	Ind.		Appoquinimink River		Site Shut Down
DE 0050920	Keysor Corp.	Minor	Ind.	A		Motiva Sluiceway	Site Shut Down
DE 0000167	Kraft Foods	Minor	Ind.		St. Jones River	Puncheon Run	Redirected Discharge to Kent Co. Treatment Plant

[1] *"Sub-basin" and "River" are blank if discharge is directly to the Delaware River*

There are 44 facilities within the basin that have reported under TRI since reporting began in 1988. Reporting facilities are concentrated in the Delaware City industrial complex and in the greater Dover area. The TRI is managed by the Emergency Planning and Community Right-to-Know (EPCRA) Reporting Program.

Nitrates are a type of nitrogen nutrients. Since 1995, nitrate compounds have been reportable under TRI. Two TRI facilities within the Delaware Bay and Estuary Basin reported nitrate releases to surface waters for 2001. Motiva Enterprises reported the annual release of 530 pounds of nitrates to the Delaware River, while Perdue Georgetown reported 310,000 pounds for 2001 to the Savannah Ditch, a tributary of Broadkill River.

2.3.7 INVENTORY OF POTENTIAL CHEMICAL SOURCES

2.3.7.1 Landfills

Waste disposed of in landfills and dumps can be a source of a wide variety of contaminants. Rain water seeping through a landfill dissolves or leaches out contaminants present in the waste. The resulting leachate, if not properly managed and contained, may contaminate nearby ground water and surface water. The composition and concentration of the leachate depends on the type and volume of waste in the landfill. The landfills and dumps in Delaware primarily contain:

Municipal waste - trash from households, offices, and stores with significant amounts of putrescible food waste;

Miscellaneous non-putrescible waste - waste from road clean-up activities, construction and demolition activities, old appliances, etc.; and/or

Coal ash - from combustion of coal to generate electric power and steam.

Leachate from municipal waste landfills is typically high in complex organic degradation compounds, ammonia, chlorides, alkalinity, chemical and biological oxygen demand (COD and BOD), iron, and sulfate. It may also have smaller amounts of volatile organic compounds and heavy metals. Besides leachate, municipal waste landfills also generate large amounts of methane gas.

Leachate from miscellaneous non-putrescible waste landfills is typically high in alkalinity, iron, and sulfate, but lacks the organic decay products and ammonia typical of municipal waste leachates. It may also contain smaller amounts of volatile organic compounds and heavy metals. Miscellaneous non-putrescible waste landfills can generate methane gas if they contain wood waste and hydrogen sulfide gas if they contain gypsum wallboard.

Leachate from coal ash landfills is typically high in sulfate and iron and often contains a variety of heavy metals, including arsenic. These landfills do not generate gases.

The Delaware Solid Waste Authority operates three municipal solid waste landfills in Delaware, one in each county. Two of these active landfills are located in the Chesapeake drainage basin. One is located adjacent to the Port of Wilmingtom along the Delaware River (technically a part of the Delaware Bay and Estuary Basin but has been included in the Piedmont Basin which addresses the six northernmost watersheds in Delaware). There are a number of inactive, closed, landfills in the Delaware Bay and Estuary Basin.

2.3.7.2 Tire Piles

There are 13 known large waste tire piles in the Delaware Bay and Estuary Basin (*refer to Map 2.3-3 Known and Potential Chemical Sources*). The piles contain 500 to 50,000 tires for each pile. Other than serving as a breeding ground for mosquitoes, these tire piles are causing no apparent environmental problems. However, these piles do present a significant environmental risk if they catch on fire. Tire pile fires are very difficult to put out. Large tire piles may burn for weeks before being extinguished. Tire pile fires generate large amounts of noxious smoke that may necessitate evacuation of downwind residents. The fires also generate organic liquids that can contaminate ground water and surface water.

2.3.7.3 Hazardous Waste Facilities

The Solid and Hazardous Waste Management Branch (SHWMB) regulates facilities that generate, accumulate, transport, treat, store, or dispose of hazardous waste. Hazardous waste is commonly generated by manufacturing processes that supply many products and services. If released, hazardous waste has the potential to cause notable harm to human health and the environment. Hazardous waste can be of two types:

Listed hazardous waste - Listed hazardous wastes are specifically identified in the Delaware Regulations Governing Hazardous Waste. Currently, there are more than 400 such wastes listed. The wastes are listed as hazardous because they are known to be harmful to human health and the environment.

Characteristic hazardous waste - Even if a waste is not listed, it may still be regulated as hazardous if a characteristic of hazardous waste is exhibited. Characteristics of a hazardous waste include ignitability, corrosivity, reactivity, and toxicity.

Within the Delaware Bay and Estuary Basin, 342 facilities are identified as hazardous waste generators. One hundred and eighty nine (189) of these generators are in New Castle County, 93 in Kent County, and 60 in Sussex County. In addition to hazardous waste generators, there are several hazardous waste treatment, storage, and/or disposal (TSD) facilities located within the Basin.

Although all facilities regulated by the SHWMB have the potential to release contaminants to the environment, most facilities manage their wastes in a responsible manner and, thereby, minimize the possibility of a release occurring. Furthermore, the proactive regulatory stance adopted by the SHWMB has increased companies' awareness and usage of proper hazardous waste management practices.

2.3.7.4 Hazardous Chemical Inventory Reporting Facilities

Facilities report under the Hazardous Chemical Inventory for each hazardous chemical (as defined by OSHA) or extremely hazardous substance (EHS) present above threshold quantities. The basic threshold is 55 gallons or 500 pounds, whichever is lower, based on the maximum amount present on site at any time during the calendar year. Certain EHSs have a lower threshold. For each chemical or mixture, facilities report the identity of the substance, the amount present, and storage location information. This information has three primary purposes. Local emergency planning committees (LEPCs) use it to develop plans to prepare for and respond to chemical emergencies in their districts. The 911 fire dispatch centers access the chemical information during emergencies at facilities, and provide this information to local fire fighters and other emergency personnel responding to the site. The information is also available to the public to promote public participation in managing chemical risks in the community.

Approximately 1,300 facilities statewide report chemicals each year to the Hazardous Chemical Inventory, with an estimated 450 of these facilities located in the Delaware Bay and Estuary Basin (*refer to Map 2.3-3 Known and Potential Chemical Sources*). The data are made available to emergency planning and response organizations through the Computer-Aided Management of Emergency Operations, or CAMEO, data system. The CAMEO system contains basic facility information such as facility name and street address, as well as the chemical-specific inventory information. CAMEO also contains a variety of other data modules used for emergency planning and response.

CAMEO runs in conjunction with a basic GIS mapping system named MARPLOT. The LEPCs are responsible for plotting the facilities within their district in MARPLOT. While the New Castle County LEPC has plotted their facilities, the LEPCs for Kent and Sussex have not. MARPLOT layers should be easily transferred to the Department's GIS system for inclusion in watershed assessments. While these facilities report only the presence of chemicals and not releases to the environment, a geospatial representation of these facilities could contribute to the Department's overall knowledge of potential sources of chemical contamination.

2.3.7.5 Toxics Release Inventory (TRI) Reporting Facilities

Manufacturing facilities report annually under TRI on any reportable toxic chemical that is manufactured, processed or otherwise used above certain thresholds. The reportable list includes 582 individual chemicals and 30 chemical categories. Reports contain data on releases of the specific chemical to air, water, and land, as well as information on chemical in wastes transported off-site or managed on-site.

There are 44 facilities within the basin that have reported under TRI since reporting began in 1988. Reporting facilities are concentrated in the Delaware City industrial complex and in the greater Dover area.

2.3.7.6 Superfund Sites

The investigation and remediation of many of the country's most serious hazardous waste sites are performed through the Federal Superfund Program, which established a National Priority List (NPL) of the worst sites. In 1990, Delaware enacted the Hazardous Substance Cleanup Act (HSCA), administered by the Site Investigation and Restoration Branch (SIRB), to deal with other potentially harmful sites not addressed through the Federal Program. In 1993, the SIRB Branch initiated the Voluntary Cleanup Program (VCP) which is administered under the Hazardous Substance Cleanup Act. The VCP is primarily designed to address the properties that are being evaluated for transaction or redevelopment and properties where no immediate threat to human health or the environment exists.

There are 185 Superfund sites that have been identified in the Basin (*refer to Map 2.3-3 Known and Potential Chemical Sources*); over 40 are actively being investigated by the SIRB Branch. The remaining "inactive" sites have either been previously investigated or are of relatively low priority based on the determination that they likely present minimal environmental impact.

Additional information regarding Site Investigation and Restoration Branch sites may be found at http://www.dnrec.state.de.us/dnrec2000/Brownfields.asp

2.3.7.7 Underground Storage Tank Sites

Leaking underground storage tank (UST) sites have been the source of over 2,000 reported releases of chemical contaminants into Delaware's environment for the past 20 years. Contaminant releases often result from:

- Corrosion, breaks, ruptures or other types of structural damage in the tank or associated piping, dispensers or other tank system components;
- Loose fittings in the tank system piping, associated dispensers or other tank system components; or
- Spills and overfills that routinely occur during tank filling and dispensing operations.

Except for spills and overfills, contaminants from UST systems are released below ground. Released contaminants (including petroleum products) migrate downward through backfill, soils, and sediments surrounding the tank to the water table. Most products stored in USTs have a specific gravity that is less than one. As a result, any free-phase product that makes it to the water table not only floats on ground water but will migrate in the direction of ground-water flow. Because the water table in the Delaware portion of the Delaware Bay and Estuary Basin is often within ten feet of the ground surface, a very small release from an UST system may be sufficient to contaminate ground water and/or sensitive receptors. Sensitive receptors impacted by UST systems include, but are not limited to, water supply wells, surface water bodies, utility lines or conduits and building basements which can cause an explosive situation.

A tank owner or operator may not suspect a release due to the fact that the tank system is not equipped with functioning leak detection equipment, and/or the operator is not trained to use the equipment properly. Also, many times the leak rates are very low compared to the amount of fuel dispensed and the leak may be difficult to detect. If leaks continue undetected for a considerable time, the potential for substantial environmental damage increases dramatically and sensitive receptors may become impacted. When sensitive receptors are impacted, the costs associated with cleaning up the contaminants increases substantially. The goal is to limit the amount of contaminants released by using leak detection equipment, which in turn will minimize the impact to the environment and keep the costs for cleanup down.

UST site releases have become a growing concern in Delaware over the past 20 years, especially because water wells and other sensitive receptors have been impacted.

Most UST systems in Delaware store petroleum products which include, but are by no means limited to: gasoline, kerosene, jet fuels, diesel fuel, heating oil, and used oils. USTs may also contain a variety of hazardous substances, such as chlorinated solvents.

Petroleum products can contain more than 100 different hydrocarbon compounds, many of which have been shown to be toxic to humans and wildlife. For example, benzene, a common constituent of gasoline, has been shown from epidemiological studies to be a human carcinogen. Benzo(a)anthracene and benzo(a)pyrene, which are common constituents of heating fuels, are probable human carcinogens.

Chemical compounds are commonly added to petroleum products to make these products burn more efficiently, and to reduce emission of toxic chemical compounds into the air. For example, the Federal Clean Air Act Amendments of 1990 require that gasoline dispensed in Delaware contain up to 15 percent methyl tertiary butyl ether (MTBE). Unlike benzene and other hydrocarbon compounds present in petroleum, MTBE does not significantly biodegrade in the natural environment, and dissolves into ground water much more easily, thus making remediation more difficult. Dissolved MTBE molecules migrate through ground water much more rapidly than other hydrocarbon compounds. As a result, MTBE is usually one of the first chemicals from a release to impact drinking water supplies. The EPA is currently conducting studies to determine whether MTBE is a carcinogen. MTBE contamination is of great concern because it has been documented in an increasingly greater number of new and existing leaking UST sites over the past few years.

Historically, there have been 920 registered UST facilities and 886 identified leaking UST events located in the Delaware Bay and Estuary Basin. Many facilities have had more than one leaking UST event and many facilities have removed all of their UST systems. 217 leaking UST sites are active, with the remainder closed or de-activated by the Department. Essentially, closed or inactive leaking UST sites are those sites where site investigation and remedial actions have been completed, and apparent threats to human health, safety, or the environment have been eliminated. Thus, the UST Branch requires no further action at closed or inactivated sites.

Although no data exist on the number of active sites in the Basin prior to 1997, it is likely that trends for the Delaware portion of the Delaware Bay and Estuary Basin are similar to those of the entire State. That is, available data show that the number of active sites statewide increased rapidly from 1983 through 1990, and then leveled off at about 550 sites. The number of active sites will likely slowly decrease over the next several years.

Any UST site in the Basin, even one where no known release has occurred, is a potential source of contamination. Concern for releases is genuine, as even a small release can impact and degrade ground water due to occurrence of the water table so close to the ground surface. Each registered UST site is plotted on *Map 2.3-3 Known and Potential Chemical Sources*.

It is important to note that not every UST in the Delaware Bay and Estuary Basin is registered with the Department. This includes UST facilities that are "exempt", under current regulations, from registering with the Department. Most of the "exempt" USTs are heating oil tanks with capacities of 1,100 gallons or less for which no leaks or releases have occurred. Once a release has occurred, an "exempt" UST becomes regulated and the release must be cleaned up to levels that are not a threat to human health, safety, or the environment (as required at any leaking UST site). The Department has documented many cases of releases that have occurred in previously "exempt" tanks, and where stringent site remediation was required. Therefore, any currently "exempt" tank also has release potential.

Releases from "exempt" tanks are more difficult to detect and track because the Department does not regulate them. Detection occurs only during property transfer proceedings, or after a sensitive receptor, such as a water well, is impacted. Thus, it is likely many releases have occurred from "exempt" tanks that the Department is not aware of, whereas those from regulated tanks under similar circumstances would likely be known. The relative lack of release data for "exempt tanks" represents a major data gap at UST sites.

Ground-water contamination has been documented in 250 leaking UST events in the Delaware Bay and Estuary Basin. Severe ground-water contamination, including the presence of free-phase hydrocarbons, has been documented for 79 leaking UST events. Off-site contaminant migration has been observed at 20 leaking UST events.

Current UST regulations require that any UST installed after 1985 must comply with "new" tank standards, including protection against corrosion, and be equipped with spill and overfill protection and leak detection equipment. New tank systems cannot be put into operation until they pass a precision tank test to determine if the tank is leaking. Those tanks installed before the regulations went into effect in 1986 must have been either upgraded to comply with new tank standards before 1991 (except for corrosion protection), or be removed from the ground. Existing tanks still not equipped with adequate corrosion protection by 1998 must be either upgraded to comply with new tank corrosion protection requirements, or be removed. Inventory control, record keeping, precision tank testing, as well as monitoring of leak detection equipment (including vapor and observation wells) and corrosion protection equipment are required by owners and operators of all regulated USTs.

The major challenges of the Underground Storage Tank Branch are to (1) ensure that tank owners and operators bring their tanks into compliance with the regulations; (2) report any releases; and (3) effectively remediate contamination released at UST sites.

2.3.7.8 Large On-Site Community Disposal Systems

Large community septic systems are a potential source of chemical contamination. The typical contamination is consumable salts, especially chloride. However these systems can also act as rapid pathways for various household chemicals (degreasers, cleansers, etc.) to the subsurface.

2.3.7.9 Land Treatment of Wastes

Land application sites can vary in regard to their chemical constituent concentrations. The main chemicals of concern in the Delaware Bay and estuary Basin for industrial facilities are sodium and chloride. Chloride is also a potential contaminant from domestic wastewater facilities. Although many treatment systems receive other chemicals from domestic wastewater, the treatment process generally removes any chemical contaminants through aeration, volatilization, and chemical breakdown prior to land application.

2.3.7.10 Dredge Spoil Areas

Chesapeake and Delaware (C&D) Canal. The C&D Canal is a navigational waterway to the Port of Baltimore maintained by the U.S. Army Corps of Engineers. The canal system provides a continuous sea-level channel connecting the Port of Baltimore to the northern ports of Wilmington, Philadelphia, and northern trade routes.

The Federal government owns nearly 9000 acres along the C&D canal, and leases roughly 180 acres. The leased Federal land is used for agricultural (39 acres) and disposal purposes, as well as for habitat and recreational purposes. Most of the unleased Federal land (5,426 acres) along the canal is used for disposal of material resulting from maintenance dredging performed to sustain the authorized channel dimensions. *Map 2.3-3 Known and Potential Chemical Sources* shows locations of the dredge disposal areas.

Man-made embankments along the canal are the result of years of disposal activity and maintenance to authorized canal depths. Through a series of agreements, the States of Delaware and Maryland manage approximately 7,500 acres of property for recreation and wildlife management. These areas encompass historically filled disposal areas as well as many active (diked) disposal areas.

Nineteen upland disposal sites have been actively used by the Federal Government over the last 25 years for maintenance dredging of the C&D Canal. A ten-year monitoring program was initiated in 1987 to monitor heavy metal concentrations in vegetation, surface water, and ground water. The Department and the Maryland Department of Natural Resources conducts soil, groundwater, and surface water sampling on a regular basis. To date, results show no environmental impact on the sampled media.

2.3.7.11 Pesticide Mixing, Loading, and Storage Locations

These sites store, mix, and load pesticide products, liquid fertilizers, and solid fertilizers. The products are usually purchased in large bulk quantities, and stored in individual packages in a warehouse, or in large mixing tanks, drums, or minibulk containers.

Product may potentially be released during mixing or loading into transporter or application equipment. The product storage containers may also fail. While some sites have modern containment systems, including dikes, berms, and product recovery systems, others do not.

Currently, the design of such facilities is not regulated. Consequently, no data are available on pesticide/fertilizer releases from mixing, loading, or storage areas.

2.3.7.12 Salt Piles

There are over 20 Department of Transportation road maintenance facilities located throughout the state. All of these facilities store salt in buildings located onsite. Of these facilities, approximately 10 are located within the Delaware Bay and Estuary Basin. While most of the buildings are completely enclosed, a number are constructed with openings in the walls of the structures. Rain has the potential to leach salt from the piles into surrounding surface and ground water. More investigation needs to be performed to determine if the salt piles are adequately protected from exposure to weather during storage and transfer.

2.3.7.13 Salvage Yards

Automobile salvage yard and scrap metal recycling facilities provide a valuable service by recovering and recycling usable materials from discarded vehicles and equipment. While salvage operations are beneficial, the associated products and generated wastes have the potential to harm human health and the environment. Products and wastes from salvage operations include: used oil, antifreeze, spent solvents, refrigerants, petroleum fuels, lead containing wastes (e.g., batteries), tires, automobile fluff and other solid wastes. Mismanagement of these products and wastes contributes to soil, water and air pollution. Additionally, data exist that can link mismanagement of salvage materials containing polychlorinated biphenyls (PCBs) to the degradation and contamination of water systems. PCB contamination is responsible for the continued fish advisory precautions placed on numerous water bodies throughout Delaware.

2.3.8 AIR QUALITY

2.3.8.1 Introduction

In 1970 Congress amended the Clean Air Act of 1963 and authorized the EPA to establish National Ambient Air Quality Standards (NAAQS) for pollutants shown to threaten human health and welfare. Primary standards were set according to criteria designed to protect public health, including an adequate margin of safety to protect sensitive populations (e.g., children, asthmatics, and the elderly). Secondary standards were set according to criteria designed to protect public welfare (decreased visibility, damage to crops, vegetation, buildings, etc.).

Six principal pollutants currently have NAAQS: ozone (O_3), carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), particulate matter (PM_{10}), and lead (Pb). These are commonly referred to as the criteria pollutants. When air quality does not meet NAAQS, the affected area is said to be in non-attainment with NAAQS. Currently, there are no standards for acid rain, nitrogen deposition, or air toxics.

Delaware's land surface is relatively flat, and because of this condition, outdoor or ambient air moves fairly smoothly through and is generally well mixed across the entire state. The predominant airflow is from west to east. In the summer, southwesterly winds prevail while in the winter northwesterly winds are dominant.

2.3.8.2 Status

Air quality in the Delaware Bay and Estuary Basin meets all NAAQS except for ozone, with $PM_{2.5}$ status yet to be determined. New Castle and Kent Counties are classified as serious non-attainment areas for ozone while Sussex County meets the one-hour standard, but not the new eight-hour standard. The acid rain monitor shows precipitation to average around pH 4.2 to 4.3 (acidic).

Ozone (O3)

Ozone is a highly reactive gas that is the main component of smog. While ozone in the upper atmosphere (stratosphere) is beneficial because it absorbs ultraviolet light, it is a pollutant in the lower atmosphere (troposphere). Ozone is a strong respiratory irritant that affects healthy individuals as well as people with impaired respiratory systems. It can cause respiratory inflammation and reduced lung function. It also adversely affects trees, crops (soybeans are a particularly sensitive species), and other vegetation. Ozone is also implicated in white pine damage and reduced growth rates for red spruce at high elevation sites.

Ozone is not emitted directly by a pollution source but is formed in the atmosphere by the reaction of nitrogen oxides and volatile organic compounds in the presence of sunlight and warm temperatures. Therefore, ozone is basically a problem only in the summer months. In Delaware, the season for ozone monitoring runs from April through October. Although there are no ozone monitors in the Delaware Bay and Estuary Basin, air quality is similar across the state and is represented by the six monitors throughout Delaware.

Ozone trends are difficult to measure because of the complex nature of weather. In general, ozone concentrations in recent years (1990s) have been significantly lower, with fewer exceedances of the standard, than during similar weather patterns in the 1980s. Improvement is due to corrective measures such as improved pollution controls on large industrial sources, vapor recovery on gasoline pumps, and lower volatility of gasoline and various solvents.

Sulfur Dioxide (SO_2)

Sulfur dioxide is a pungent, poisonous, colorless gas. It is an irritant that can interfere with normal breathing functions, even at low concentrations. It aggravates respiratory diseases such as asthma, emphysema, and bronchitis. Particulate levels increases can magnify the severity of these conditions. Sulfur dioxide can also cause plant chlorosis and stunted growth. Sulfur dioxide is monitored at one site (Delaware City) in the Delaware Bay and Estuary Basin. This site is influenced by a nearby point source (Motiva). Other SO_2 sites in Delaware are more representative of areas not influenced by point sources.

Sulfur dioxide levels declined rapidly in the 1970s and have remained fairly steady over the last 10 years. The improvement is largely due to the change to low or lower sulfur fuels in power plants as well as to improved emission control technologies.

Particulate Matter (PM_{10})

PM_{10} is the portion of total suspended particulates that is less than 10 microns in diameter and thus, small enough to be inhaled into the lungs. PM_{10} can include solid or liquid droplets that remain suspended in the air for various lengths of time. Particles small enough to be inhaled can carry other pollutants and toxic chemicals into the lungs. Major effects of PM_{10} include aggravation of existing respiratory and cardiovascular disease, alterations in immune responses in the lung, damage to lung tissue, and premature mortality. The most sensitive populations are those with chronic obstructive pulmonary or cardiovascular disease, asthmatics, the elderly, and children. Particulates are also a major cause of reduced visibility and can be involved in corrosion of metals (acidic dry deposition).

Carbon Monoxide (CO)

Carbon monoxide is a colorless, odorless, poisonous gas produced by incomplete combustion of fossil fuels. It reduces the blood's ability to carry oxygen. Exposure can cause fatigue, headache, and impaired judgement and reflexes at moderate concentrations; at high levels unconsciousness and death can result. People with heart disease, angina, emphysema and other lung or cardiovascular diseases are most susceptible.

There has been a slight downward trend in CO concentrations since monitoring began in the 1970s, and no violations of the ambient standards have occurred since 1977.

Improvements are largely due to cleaner burning engines in cars and tighter automobile emission standards.

2.3.9 AIR SOURCES

2.3.9.1 Air Sources in the Delaware Bay and Estuary Basin

The federal Clean Air Act Amendments of 1990 (CAAA) required Delaware to inventory baseline air emissions beginning in 1990. Delaware must subsequently inventory air emissions every three years in order to show reasonable progress toward attainment of the National Ambient Air Quality Standards (NAAQS). These inventories are prepared on a countywide basis. Sources of air emissions are classified by the nature of the emissions and the physical characteristics of the emitter. Source categories of air emissions within the Delaware Bay and Estuary Basin for which data are collected include stationary point sources, stationary area sources, mobile sources, and biogenic sources. *Figures 2.3-2 through 2.3-4* illustrate VOC, NO_x and CO emissions by county and source category.

The five source categories are defined as follows:

Stationary Point Sources

A stationary point source is defined as a facility that emits 10 tons per year (TPY) or more of volatile organic compounds (VOCs) or 100 TPY or more of oxides of nitrogen (NO_x) or carbon monoxide (CO).

Stationary Area Sources

Stationary area sources represent a collection of many small, unidentified points of air pollution emissions within a specified geographical area, all emitting less than the level attributed to stationary point sources. Since these sources are too small and/or too numerous to be characterized individually, all area sources must be identified and emissions from these activities collectively estimated. Area sources can be grouped into four types of general activity categories:

1. Fuel combustion sources;
2. Solid waste incineration and open burning sources;
3. Fugitive dust sources; and
4. Volatile organic compound sources.

Mobile Sources

Mobile sources of air emissions are divided into on-road and off-road categories of activity. On-road emissions are those attributed to all vehicular traffic active on the state's highway network. Quantities of emissions are indirectly calculated through the use of both a travel demand model and a mobile emissions simulation model. The off-road emissions category includes a diverse set of source types. The movement of sources in this category occurs on surfaces other than the public highway system and includes the following sources: aircraft, locomotives, marine vessels, and other off-highway vehicles and equipment. These emissions are estimated through a series of complex simulation equations. Pollutant emissions estimated for these two categories during the statewide inventory process are VOCs, NO_x, and CO.

Biogenic Sources

Biogenic air emissions are those which originate from naturally occurring sources, with vegetation being the primary contributor. Air pollutant emissions from these sources are estimated through a computer simulation model. As NO_x and CO emissions from natural sources are negligible, only VOC emissions were estimated for this category during the statewide inventory process.

Air Toxics Sources

As required by the federal government, more than 650 toxic chemicals are subject to release reporting by industrial and manufacturing facilities on an annual basis. Sources of air toxics include many types of large and small industrial facilities, as well as, mobile sources. The Toxic Release Inventory, prepared by the Department, contains annual data from specific larger industrial facilities that manufacture, process, and/or use toxic materials.

2.3.9.2 Regional transport versus local sources

The regional transport of ground-level ozone and ozone precursors over long distances is a serious regional problem in the eastern United States. For example, even if all emissions sources within the Basin were controlled, upwind sources such as Washington, DC and Baltimore, Maryland would still produce episodes of unhealthy air quality and exceedances of the NAAQS within the Basin. Consequently, the states involved are working together to address the problem.

Two organizations formed under authority of the federal

FIGURE 2.3-2
DISTRIBUTION OF PEAK OZONE SEASON DAILY VOC EMISSIONS

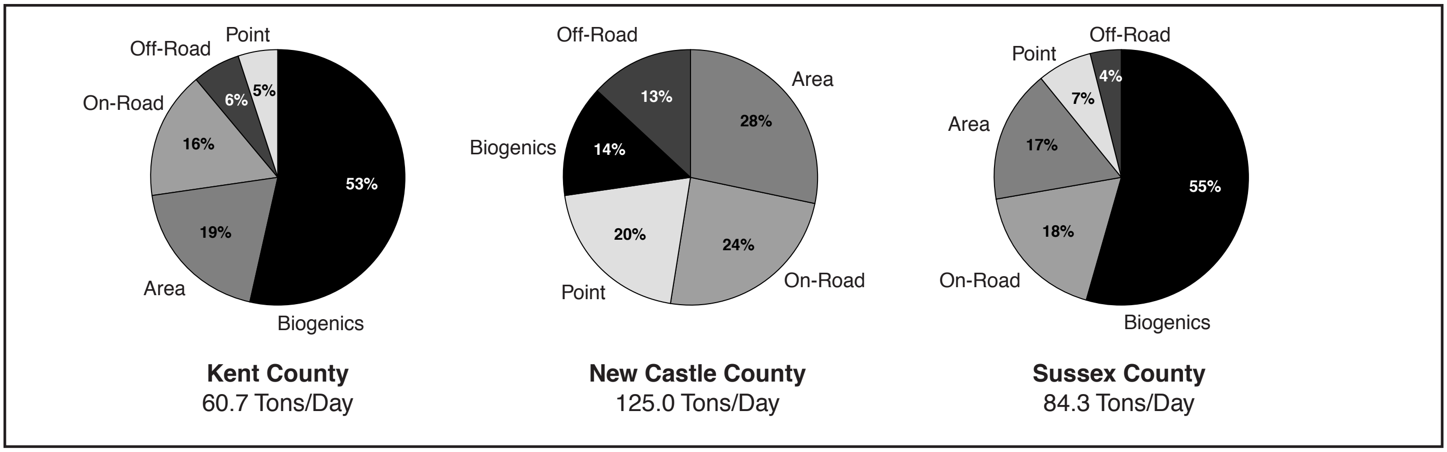


FIGURE 2.3-3
DISTRIBUTION OF PEAK OZONE SEASON DAILY NOx EMISSIONS

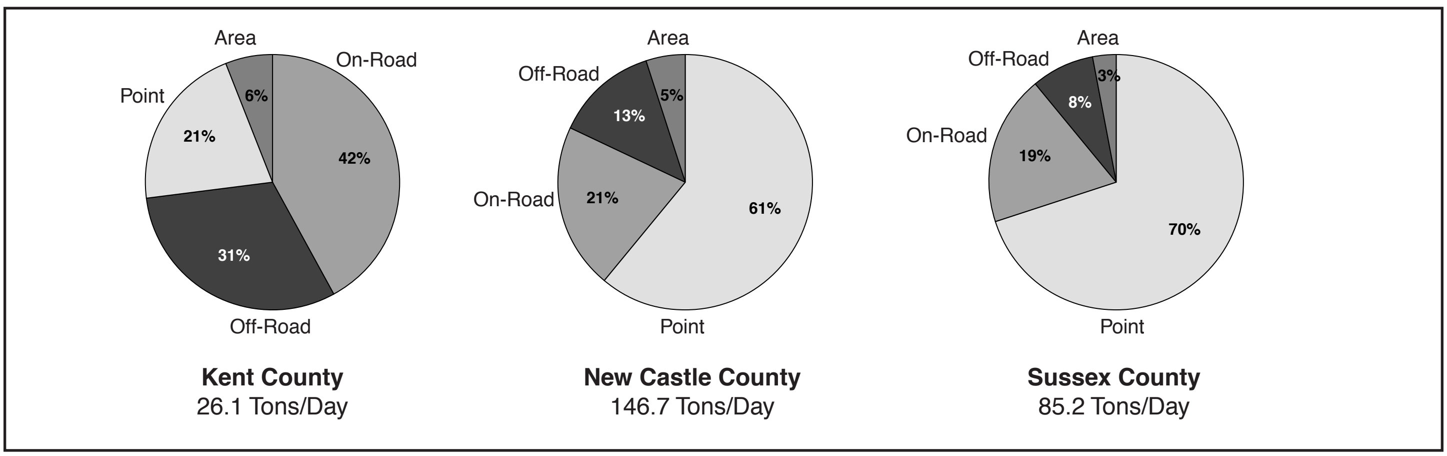
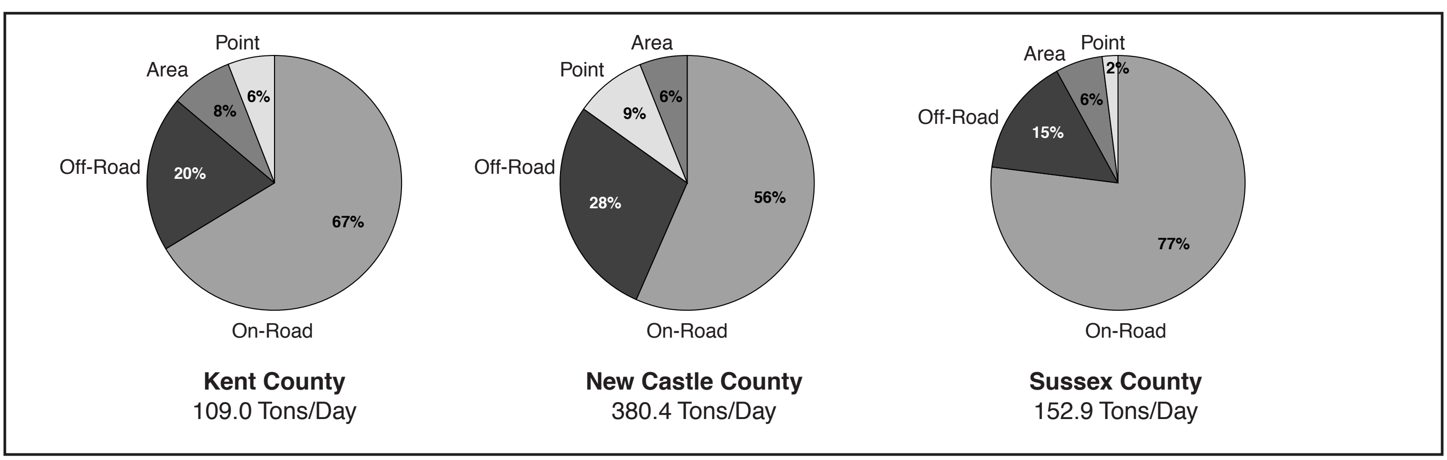


FIGURE 2.3-4
DISTRIBUTION OF PEAK OZONE SEASON DAILY CO EMISSIONS



Clean Air Act, the Ozone Transport Assessment Group (OTAG) and the Ozone Transport Commission (OTC), were formed to examine the mechanisms and likely controls of ozone transport within the United States. The OTAG, made up of representatives from the 38 states east of the Rocky Mountains, prepared a report outlining specific recommendations to the EPA for the control of the transport of ozone and ozone precursors. OTAG disbanded in June 1997. The OTC addresses ozone and ozone precursor formation and transport within the Ozone Transport Region (OTR), which extends along the Atlantic Coast from Virginia to Maine. This Commission currently maintains a full-time staff and is comprised of governmental leaders and environmental officials from all the member states, the District of Columbia, and the EPA.

2.3.9.3 Atmospheric Pollutant Deposition

Chemicals are removed from the atmosphere and deposited on surfaces through a variety of mechanisms. Deposition can occur through both wet (rain, snowfall, and fog) and dry processes. Both gases and particles can interact with water droplets as well as other chemical compounds to form contaminants that deposit in the Delaware Bay and estuary Basin. As with ozone, atmospheric transport from varying distances plays an important role. The importance of atmospheric deposition to ecosystem health is becoming recognized, but knowledge of the related physical and chemical processes is minimal.

Dry deposition

Dry deposition consists of any type of particle that is deposited on a surface. Organic as well as inorganic compounds and trace metals can be a part of this deposition. Delaware has yet to monitor dry deposition in the Delaware Bay and Estuary Basin.

Sulfur compounds

Sulfur dioxide can bind to dust particles and aerosols in the atmosphere, traveling long distances on the prevailing winds. It can be oxidized to a sulfate ion (SO_3) and then combine with water vapor to form sulfuric acid and fall as acid rain. Sulfur compounds also contribute to visibility degradation. The only current monitoring of sulfur compounds in the Delaware Bay and Estuary Basin is for SO_2 (as described previously).

"Acid Rain"

Acid rain (more properly called acid precipitation) is rain, snow, or fog that contains sulfuric and/or nitric acids. It results from the reaction of sulfur and nitrogen oxides released from various combustion processes with water in the atmosphere to form acids. These chemical compounds can travel for many miles in the air before falling in acid rain.

The National Atmospheric Deposition Program (NADP) reported an improvement in the acidity of precipitation in 1995, particularly in the Mid-Atlantic and New England regions.

Delaware relocated its acid rain monitor from Lums Pond/ Summit Bridge to Ommelanden Range, a state-owned property located in the Delaware Bay and Estuary Basin, in 2000. While there is not enough data yet to characterize deposition at the new site, the NADP data indicate widespread improvements that include the area of the Basin.

Nitrogen compounds

Reactions between nitrogen oxides and other compounds in the atmosphere can form nitric acid, which contributes to the acid rain problem. Atmospheric deposition of oxides of nitrogen can be a significant source of nitrogen to estuarine systems. Other reactions can produce nitrate compounds that affect visibility. There is no current monitoring of nitrogen compounds in the ambient air of the Delaware Bay and Estuary Basin.

Recent studies have indicated that industrial sources such as power plants contribute the largest portion of nitrogen deposition in the western part of the Chesapeake Bay watershed. Mobile sources contribute the largest portion of nitrogen in the eastern part, which includes the Delaware Bay and Estuary Basin (EPA, 1997). Nitrogen compounds deposited as either acid rain or dry deposition contribute to the total nutrient loading in a watershed. Studies conducted in the Chesapeake Bay Program indicate that 21 to 27 percent of the total nitrogen loading to the Chesapeake Bay is a result of atmospheric deposition. Computer modeling studies have defined the Chesapeake Bay Airshed (the region that contributes 80 percent of the deposition falling into the Bay Watershed) as approximately five times larger than the watershed.

Although Delaware does not monitor for nitrogen deposition in the Delaware Bay and Estuary Basin, data from the NADP monitors can be used to estimate deposition rates. Data from the 1997 annual NADP report show wet deposition rates of 6.8 kg/ha in the area of the Delmarva Peninsula (NADP, 1998).

2.3.9.4 Air Toxics

Air toxics is a term often used to refer to chemicals which are toxic, or suspected of producing a toxic response through human exposure. The complex chemical composition of these compounds, as well as the great number of them, makes comprehensive monitoring difficult. In northern Delaware, the Department has conducted limited monitoring for specific compounds in the City of Wilmington and in some areas near large point sources such as Delaware City.

Annual Point Source Inventory - This inventory is compiled annually. It covers emissions of VOCs, NO_x, CO, SO_2, PM_{10}, TSP, and Pb from facilities that are major emitters or potential major emitters of at least one of these pollutants. This inventory has been generated since 1990; there are currently no written reports of these inventories, but emissions summary printouts can be generated from the computer database, I-STEPS

Toxic Release Inventory - The Toxics Release Inventory (TRI) contains annual data from large industrial facilities that manufacture, process, or otherwise use toxic chemicals.

The Permitting & Compliance Group of the Air Quality Management Section maintains air permits for various processes that emit air toxics. While these permits do not provide actual emissions data, they do provide information regarding the potential to emit and the controls that exist to reduce that emission. Specific toxic chemicals, called Hazardous Air Pollutants (HAPs), are regulated under these permits.

2.3.10 DATA GAPS AND RECOMMENDATIONS

1. Encourage and support the efforts of the local emergency planning committees (LEPCs) to map the facilities in their districts and to periodically update information.

2. More investigation is needed to determine if the salt piles are adequately protected from exposure to weather during storage and transfer.

3. The Ground Water Discharges Section's (GWDS) Technically Enhanced Permitting Process (TEPP) database has tracked septic system data since 1996; however, data exist since 1986 that needs to be entered into the database. The GWDS estimates that there are over 20,000 permits issued between 1986 and 1996. The GWDS feels one seasonal position for two years or two seasonal positions for a year would be able to accomplish this task.

4. TEPP needs to be GIS compatible in order to store coordinates of individual septic systems. GIS compatibility would allow the GWDS to locate systems by using queries for failing systems, system types, etc., which would allow the GWDS to better evaluate a permit for a septic system by using other septic systems in the same area.

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2.4 BAY AND ESTUARY ISSUES

CONTENTS

Bay and Estuary Issues

2.4.1 INTRODUCTION

The Delaware Estuary proper extends well beyond the Delaware Bay and Estuary Basin in the State of Delaware, which is the primary focus of this report. In Delaware, the Delaware Estuary proper includes both the Piedmont Basin and the Delaware Bay and Estuary Basin. The Delaware Estuary proper has more than 6.5 million people in the States of New Jersey, Pennsylvania and Delaware. It extends from the head of tide at Trenton, New Jersey to the mouth of the Delaware Bay and is defined as the area where fresh water from the river mixes with salt water from the sea. This entire drainage area supports a diverse natural environment, as well as a vital industrial base. The estuary is home to the largest population of horseshoe crabs in the world and is an integral link in the international hemispheric migratory path of numerous species of birds, including shorebirds and waterfowl. In addition to its natural beauty and habitat value, the estuary maintains the world's largest fresh water port, the second largest refining-petrochemical center in the nation, and one of the world's greatest concentrations of heavy industry. These diverse uses require a delicate balance. This section describes some of the challenges and issues that the Delaware Estuary proper presents and programs established to evaluate and address these issues.

2.4.2 BOUNDARIES

The boundary between the State of Delaware and the State of New Jersey is defined through various surveys, monumentation, agreements and legal settlements. The northernmost common point is defined by a commonality of the 12-mile arc radius originating from the city of New Castle and the mean low water mark on the New Jersey side of the Delaware River. The mean low water line was agreed to in 1934 by both states.

By statutory authority both State's are to periodically review the location and condition of the reference monuments and boundary markers. In 1986 a joint meeting of the Delaware Boundary Commission and representatives from New Jersey agreed that corrective action was needed on some of the markers. The National Geodetic Survey, which cooperates in surveying and locational matters, proceeded to relocate sites, correct for positional calculations and establish Global-Positioning-System (GPS) points. This was finished in 1992. Since that time a draft joint agreement as to the boundary location based on GPS reference has languished.

Again, this agreement only deals with the 1934 Mean Low Water agreement affecting the Delaware River portion of the boundary. As noted above, it starts at a common point of the arc radius and the mean low water area on the New Jersey side. The boundary line then proceeds southwestwardly and southwardly along the shoreline down to Carney's Point near the Delaware Memorial Bridge. It continues southwardly to Killcohook National Wildlife Refuge. It runs through the refuge and down to Fort Mott State Park. The Delaware portion of Killcohook was created through a series of levees and dredge spoils. The boundary line continues down to the mouth of the Salem River. It crosses the river and keeps going south to the south side of the mouth of Alloway Creek. It then heads west to the approximate middle of the river in the channel. In heading west it cuts off the tip of Artificial Island. The tip is in Delaware and the remaining area is in New Jersey. This is the extent of the area covered under the current draft joint agreement to set the points by GPS. The above-described boundary is on the following U.S.G.S. quadrangle maps (from north to south, generally): Marcus Hook, Penns Grove, Wilmington South, Delaware City, and Taylor's Bridge. The boundary line then generally follows the middle of the shipping channel down to a point between the Cape May Light and a light at the southeast point of a breakwater to the northeast of the Harbor of Refuge in Delaware. This is noted as an indefinite point on the Cape Henlopen quadrangle. From this point the boundary is to head east passing through the mouth of the Delaware Bay seaward to the respective limits of the states of Delaware and New Jersey. The boundary line starting at the north to this point was all laid out in a 1934 U.S. Supreme Court Decree in a case of New Jersey v. Delaware.

2.4.3 CONTAMINANTS

The Delaware Estuary Program (DELEP) has identified the presence and continuing contribution of polychlorinated biphenyls (PCBs) as one of the greatest concerns currently facing the Delaware Estuary. Consequently, PCBs in the estuary heads the list of DELEP's "issues of central and cross-cutting concern." A study carried out by the DELEP Toxic Advisory Committee and discussed in a 1998 report entitled *Study of the Loadings of Polychlorinated Biphenyls from Tributaries and Point Sources Discharging into the Tidal Delaware River* focused on two classes of potential sources of PCBs in the Delaware Estuary: wastewater treatment plants and tributaries. The results indicate that wastewater treatment plants and tributaries discharging to the tidal Delaware River are active and significant sources of PCBs are still coming into the system. These findings demonstrate that current fish contamination problems cannot be attributed solely or predominantly to historic sediment contamination in the estuary.

The DELEP has drafted a strategy to deal with the overall issue of PCBs in the Delaware. To better characterize loadings from point sources, work has begun on a PCB trackdown pilot program with municipal sewage treatment plants to identify likely sources of the PCBs that are entering the systems. Additionally, preliminary meetings have been held with industrial and municipal dischargers to discuss the monitoring of effluents. There are approximately 105 dischargers that fall into this group.

2.4.3.1 Polychlorinated Biphenyls

PCBs, or polychlorinated biphenyls, are a class of compounds produced when hydrogen atoms are successively replaced in a biphenyl molecule with chlorine atoms. Depending upon the number of chlorine atoms added and their placement, there are 209 possible combinations, or congeners, produced ranging from a single chlorine replacement (monochloro) to a replacement of ten chlorine (decachloro) atoms. Commercial formulations were supplied as mixtures called Aroclors with varying chlorine content. In the United States, Monsanto produced roughly 93 % of the 1.3 billion pounds of PCBs manufactured world-wide between 1929 and 1977, giving the different formulations numerical designations such as Aroclor 1228, 1232, 1248, etc. The "12" signifies 12 carbon atoms; the latter two numbers represent the percentage of chlorine in the formulation.

The manufacture and use of PCBs were prohibited by law in the late 1970s. However, PCBs in use that were in totally-enclosed devices like transformers, capacitors, and switches, were not required to be removed and many such devices containing PCBs are still in use today.

PCBs can be found in water and sediments of the Delaware Estuary and its tributaries, and in effluent from wastewater treatment plants (WTPs) and combined sewer overflows (CSOs). They can also be found in the tissues of resident and anadromous fish collected in the Delaware River and Bay. The states of Delaware, New Jersey and Pennsylvania have issued, and currently have in effect, fish consumption advisories for striped bass, white perch and catfish. Concentrations found in Delaware River shoal sediments exceed the No Observed Effects Level (NOEL) for PCBs at 14 of 16 stations sampled in a study by Costa and Sauer (1994) and represent an ecological risk to aquatic biota.

Because PCB manufacturing has been prohibited for almost 30 years, a commonly held view among regulators and the public is that the PCBs in the estuary are from historic sediment contamination. However, a recent report (DRBC, 1998) refutes this notion by showing PCBs are currently being transported to the estuary by WTPs, CSOs and tributary streams, and are ultimately coming from material that has been deliberately or inadvertently introduced into collection systems or transported from watersheds.

The DRBC study showed that PCBs enter the estuary at much higher rates during wet weather events than during dry weather. Concentrations in tributaries are higher during wet weather. However, WTP effluent concentrations remain relatively unchanged in wet weather and dry weather. Contributions from CSOs go up dramatically during wet weather and exceed the loadings from tributaries and WTP by one to two orders of magnitude. The study demonstrated that in wet weather 88% to 95% of PCB loading came from CSOs, 4% to 9% from the tributaries, and 1% to 3% from point sources. In dry weather, 95% of the measured PCB loading came from point sources with the remainder coming from tributaries. Regardless of weather, the majority of PCBs entering the estuary enters DRBC zone 3, which corresponds roughly to the area between the Tacony-Palmyra and Walt Whitman Bridges.

Loadings entering the estuary would cause the concentrations to continually rise were it not for the net flow going down the Delaware River. This flow multiplied by the PCB water quality criteria allows one to calculate the assimilation capacity (AC) which is the amount of material the estuary can assimilate without exceeding the water quality criteria. (It differs from Total Maximum Daily Load (TMDL) because it does not take into account other factors that ultimately affect the system such as adsorption onto particulate matter, biological degradation and other fate processes.) Such calculations indicate that human health-based ACs are exceeded in DRBC zones 3 to 5 during dry weather and in wet weather the ACs are exceeded in zones 2 to 5 anywhere from 100 to 10,000 fold (DRBC, 1998).

The Delaware Estuary Program (DELEP) Comprehensive Conservation and Management Plan (CCMP) identifies PCBs as pollutants of concern and gives high priority to reducing and controlling point and non-point pollution sources of this contaminant. The DELEP participants are pursuing a variety of activities to reduce and eliminate sources of PCBs including a multi-state EPA-approved plan to reduce PCB levels along a 85-mile stretch between Trenton New Jersey and the Upper Delaware Bay. DELEP, in cooperation with DNREC, has been compiling and statistically analyzing chemical fish tissue data. Subsequent efforts will focus on assembling data on chemical contaminants in fish tissue collected since 1990 in the Delaware Estuary and to review approaches taken by different states and develop Estuary-wide fish consumption advisories.

DELEP has channeled funding from several sources, including Delaware, for a proposed study of a major sewage treatment plant (STP) in the Philadelphia metropolitan area that has been identified as a significant source of PCBs in dry and wet weather. The intent is to identify potential/actual PCB sources entering the sewer system and implement load reduction measures using education/outreach, pollution prevention and regulation.

2.4.3.2 Bacteria

Fecal coliform concentrations in the tidal Delaware River have shown dramatic declines during the last 30 years. In an area of the river off Philadelphia in the summer, fecal coliform concentrations dropped from nearly 20,000 organisms/100 milliliters in the late 1960s to less than 1,000 organisms/100 milliliters in 1990.

The Delaware River Basin Commission oversees and coordinates regulatory efforts to reduce contaminants in the Delaware Basin. The Delaware Basin water body has “designated uses”: protection and propagation of aquatic life, drinking water, fishing, swimming, and so forth. If these uses are not met, then the governing regulatory agencies must find ways to bring those uses into attainment. Where uses are not met in the Delaware River, the DRBC is establishing a “Total Maximum Daily Load” (TMDL) for the pollutants causing the problems.

Table 2.4-1 summarizes the attainment of designated uses for the Delaware Basin between Cape Henlopen and the Pennsylvania/Delaware boundary.

Three designated uses are not fully met: aquatic life protection, fish consumption, and shellfish consumption. The DRBC has identified pollutants causing the non-attainment, as well as the sources of those pollutants. The causes and sources are summarized in *Table 2.4-2*.

2.4.3.3 Toxics and Fish Consumption Advisories

The Delaware Estuary Program has selected Fish Consumption Advisories as a priority issue. Currently, different collection, analysis and risk assessment procedures are used by the estuary states in establishing fish consumption advisories. The DRBC and Delaware DNREC have initiated a project to assemble chemical contamination data since 1990 for the Delaware Estuary and identify obstacles toward making risk advisory information more consistent for interstate waters. This project produced consistent advisories for the Delaware Estuary from Cape May and Cape Henlopen to the Pennsylvania border in March 2004.

The overall goal is to establish uniform or compatible fish collection and analysis procedures, and compatible fish assessment and reporting for the whole Delaware Estuary. This involves four objectives as described in the DELEP Comprehensive Conservation Management Plan (CCMP):

- Develop procedure for uniform or comparable collection and analysis method;
- Discussion of health risk procedures and recommended options for consumption advisories;
- Conduct health risk assessments; and
- Coordination of risk communications

2.4.4 DREDGING

Dredging is the act of removing land or bottom material to create and maintain channels to obtain sand, gravel and shells for construction material, to enhance navigation, to establish marinas and boatyards, and to create waterfront canals or lagoons.

The primary impact of channel dredging is the destruction of the community of organisms living on or in the land covered by water. Many important estuarine functions are affected in the areas dredged. For example, the natural contour and composition of the subsurface on which shellfish settle and grow is often removed by dredging. Aside from the direct destruction

Table 2.4-1 Designated Uses for the Delaware Basin

Individual Use Support Summary, 1996-1997[1] Delaware Bay & Estuary Zones 5 and 6) (Square Miles)						
Use	**Assessed Size**	**Full Supporting**	**Fully Supporting but Threatened**	**Partially Supporting**	**Not Supporting**	**Not Attainable**
Aquatic Life	191	36	96	49	10	0
Fish Consumption	841	0	0	0	841	0
Shellfishing	679	582	0	35	62	0
Swimming	191	191	0	0	0	0
Secondary Contact	191	191	0	0	0	0
Drinking Water	*	*	*	*	*	*
Agricultural	*	*	*	*	*	*
Cultural / Ceremonial	*	*	*	*	*	*
** Category Not Applicable*						
0 Category Applicable, but size of waters in the category is zero						
[1] *"The Delaware River and Bay Water Quality Assessment 1996-1997 305(b) Report, Part 1, Summary/Overview", page 5, Table 6, Delaware River Basin Commission, West Trenton, New Jersey, August, 1998*						

Table 2.4-2 Non-Attainment of Designated Uses for the Delaware Basin

Summary of Impaired Uses, 1996-1997[1] Delaware Bay & Estuary Zones 5 and 6)			
Area Affected (sq. miles)	**Impaired Use**	**Cause**	**Source**
59	Aquatic Life	Low Dissolved Oxygen & chronic toxicity	Point Sources
841	Fish Consumption	PCBs	Point Sources and non-point storm-water runoff
97	Shellfish Consumption	582	Point Sources and non-point storm-water runof

of habitat, dredging creates new flow patterns, in many cases introducing more saline water into dredged areas. Moving the saline-fresh-water interface upstream moves the turbid zone upstream, redistributes species and can affect domestic fresh water utilities that depend on surface intakes. For more dredging information, see Section 2.6.10.4.

2.4.4.1 Spoil Disposal

Spoil is the sand, clay, mud, muck, shell or other material removed by dredging which must be either discarded or, preferably, put to some constructive use. Dredge spoils may be placed on land as in a confined disposal facility, or used to construct wetlands or replenish beaches, or discharged overboard. When it is discharged overboard it can go directly offshore or to a dewatering barge. Economic loading is a term used to describe a dredge spoil discharge method to a dewatering barge and then to another location. The dewatering operation involves discharge of some to the material as its volume is reduced.

Disposal of spoil can be a damaging activity associated with dredging. It may damage the estuarine ecosystem by smothering aquatic life and suspending large quantities of silt in the water which sharply increases turbidity. Increased turbidity reduces the amount of light penetrating the water and often leads to decreased productivity of aquatic plants and organisms. Suspended sediment also demands more oxygen from the water.

Oxygen concentration can be critical during the hot months of the year because warmer water contains less dissolved oxygen.

Suspended sediment, in addition to fertilizing the water, also reintroduces toxic materials that have been deposited in some bottom sediments in Delaware waters. Heavy metals and other compounds entering the waterways can become concentrated in fish and cause illness in humans when the fish are consumed. The growth and survival of clams, oysters, crabs, shrimp and other benthic organisms can be affected by even moderate levels of suspended sediment. As the silt settles these organisms and plants are covered. The loss of these organisms affects other animals such as fish and waterfowl.

Since many estuarine fish (such as white perch and river herring) have eggs that sink to the bottom, deposits of suspended sediment in estuaries, tidal creeks and associated fresh-water streams during spawning periods can destroy a brood stock. Layers of dead oysters, for example, can be caused by intermittent spoil disposal. Thoughtless spoil disposal not only reduces fish and shellfish harvests but can lead to the generation of biologically dead areas.

Runoff from spoil sites can contain non-point sources of pollutants. More than half of surface-water pollution is caused by non point sources. Spoil sites require continuous monitoring and maintenance.

Finally, placement of spoils can adversely affect fresh-water aquifers. Infiltration of the brackish and salty waters contained in the spoils may contaminate shallow ground-water reservoirs thereby reducing their utility for domestic, industrial and agricultural water supplies. (DCMP, 1979)

2.4.4.2 Projects in the Delaware Bay System

There are 14 actual or potential U.S. Army Corps of Engineers projects that involve dredging in the Delaware Bay system:

- Delaware River, Philadelphia to the Sea – Delaware, New Jersey, and Pennsylvania.
- Delaware River Main Channel Deepening
- Delaware River, Philadelphia to Trenton
- Delaware River at Camden
- Schuylkill River, Pennsylvania
- Wilmington Harbor, Delaware
- Wilmington Harbor Deepening Study
- Salem River, New Jersey
- Cohansey River, New Jersey
- Cedar Creek, Delaware
- Mispillion River, Delaware
- Murderkill River, Delaware
- Intracoastal Waterway, Delaware River to Chesapeake Bay, Delaware and Maryland (Chesapeake and Delaware Canal)
- Chesapeake and Delaware Canal – Baltimore Harbor Connecting Channels (Deepening), Intracoastal Waterway, Delaware River to Chesapeake Bay, Delaware and Maryland

Dredging of the Delaware River, Bay and its tributaries has and will continue to take place. Maintenance dredging is continuous to maintain the project depth to provide for safe navigation. Dredging to increase depth has some political support for improving the access for larger ships to ports along the Delaware and the C&D Canal.

2.4.5 COMMERCE

The Delaware Estuary is home of the nation's largest fresh water port. It contains one of the nation's largest concentration of heavy industry and the nation's second largest petroleum refining and petrochemical centers. About three quarters of the oil reaching the east coast is transported through the Ports of Philadelphia, Camden, Gloucester City, Salem and Wilmington (Webster, 1996).

U.S. Army Corps of Engineers (USACE) maintains statistics of waterborne traffic on the Delaware River from Trenton, New Jersey to the Delaware Bay and Atlantic Ocean. In 1998 there were about 116,000,000 short tons transported. About half of that was petroleum. There were 73,449 vessel trips to carry this cargo. (USACE, 1999) The Delaware River imports more crude oil than any port on the east coast. About 1 million barrels of oil travel up the Delaware each day. Oil tankers must be lightered to reduce their draft before transiting upstream. Lightering is the process of removing some of the cargo to other vessels. Usually barges are brought alongside the ships off Big Stone Beach where a portion of their cargo is off-loaded.

The Port of Wilmington, Delaware, is owned and operated by the Diamond State Port Corporation. The Port of Wilmington covers over 350 acres and is readily accessible to U.S. east coast markets via interstate I-95. Future expansion is planned to provide more storage capacity for existing and future commercial businesses. Rail access to the port is available via Norfolk Southern and CSX Transportation, with railcar loading docks located next to terminal warehouses. The port facilities include seven deepwater berths, a tanker berth and a floating pier for roll-on/roll-off vessels on the Christina River. See http://www.portofwilmingtonde.com for more information.

$$\frac{(2e^{9}\text{ fc x 3.3 people per boat) x (0.065 discharge rate)}}{\text{(70 total coliforms per 100 ml) / average depth}}$$

In 1999, the USACE reported that 14,556,000 short tons of cargo were transported through the Chesapeake and Delaware (C&D) Canal making it the busiest canal in the United States and third busiest in the world. The Chesapeake & Delaware Canal is 14 miles long, 450 feet wide and 35 feet deep across Maryland and Delaware, connecting the Delaware River with the Chesapeake Bay and the Port of Baltimore. The C&D Canal is owned and operated by the U.S. Army Corps of Engineers, Philadelphia District. The project office in historic Chesapeake City, Maryland, is also the site of the C&D Canal Museum and Bethel Bridge Lighthouse. See http://www.nap.usace.army.mil/sb/c&d.htm for more information.

The Cape May-Lewes Ferry launched its service in 1964 when Virginia, after the opening of Chesapeake Bay Bridge Tunnel, rendered its ferries unnecessary and sold four of them to the Delaware River & Bay Authority (DRBA) for $3.3 million. The DRBA later replaced the fleet with five newer vessels. The distance the ferry crosses is about 17 miles. The ferry can hold approximately 1000 passengers and 100 cars with a travel time of 70 minutes. See http://www.capemay-lewesferry.com/onboat/meetfleet.html for more information.

2.4.6 GOVERNANCE

2.4.6.1 Delaware River Basin Commission

The Delaware River Basin Commission (DRBC) was formed in 1961 by compact among the four basin states (Pennsylvania, New Jersey, New York, and Delaware) and the federal government. Commission members are the governors of those states and a federal member appointed by the President of the United States. The four governors appoint alternate commissioners, selecting high-ranking officials in the four-state environmental regulatory agencies.

Commission programs include: water quality protection, watershed planning, water supply allocation, regulatory review, water conservation initiatives, drought management, flood control and recreation.

Annual elections are held for Commission chair, vice-chair, and second vice-chair, based upon a rotation of the five signatory parties.

The Commission holds monthly business meetings and hearings on policy matters and water resource projects under regulatory review. These sessions, along with meetings of the Commission's various advisory committees, are open to the public.

Each commissioner has one vote of equal power with a majority vote needed to decide most issues. Exceptions are votes on the Commission's annual budget and drought declarations which require unanimity.

The Commission is funded by its signatory parties, receiving additional revenue from project review fees; water use charges; fines; and federal, state and private grants. (Roberts, 2000)

2.4.6.2 Delaware River and Bay Authority

The Delaware River and Bay Authority (DRBA) is a New Jersey - Delaware governmental organization based in Delaware between the twin-span bridges. Its functions are to operate the Twin Spans, the Cape May-Lewes Ferry, the Three Forts Ferry Crossing, the New Castle, Cape May, Millville, and Dover Civil Air Terminal Airports and to participate in economic development ventures throughout Delaware and the four southernmost counties in New Jersey such as the DRBA business center at Carney's Point, New Jersey.

2.4.6.3 Oil Spill Prevention and Recovery – Delaware Bay & River Cooperative

The Delaware Bay and River Cooperative (DBRC) office is located at the Lewes, Delaware campus for the University of Delaware College of Marine Studies at the Adrian S. Hooper Marine Operations Building. The DBRC is a partnership of companies in the petroleum and transportation industries. When an oil spill occurs in the Delaware Bay or the navigable portion of the Delaware or Schuylkill Rivers, the DBRC dispatches oil skimmers and recovery vessels to the scene. Its largest vessel is the 166-foot, 425-ton DELRIVER, which is based at the college's harbor. As the DELRIVER navigates through a spill area, two arms extend from either side, deploying state-of-the-art skimming systems. The J-shaped booms contain skimmers capable of recovering oil at a rate of 800 gallons a minute. For more information, contact: dbrcinc@aol.com

2.4.6.4 Estuary Management and Conservation

The main stem of the Delaware River extends 330 miles from the confluence of its east and west branches at Hancock, N.Y. to the mouth of the Delaware Bay. The river is fed by 216 tributaries, the largest being the Schuylkill and Lehigh Rivers in Pennsylvania. In all, the entire Delaware River Basin contains 13,539 square miles, draining parts of Pennsylvania (6,422 square miles or 50.3 percent of the basin's total land area); New Jersey (2,969 square miles, or 23.3%); New York (2,362 square miles, 18.5%); and Delaware (1,002 square miles, 7.9%).

Almost ten percent of the nation's population relies on the waters of the Delaware River Basin for drinking and industrial uses. The Delaware Bay is a one day drive for about 40 percent of the people living in the United States. Yet the basin drains only four-tenths of one percent of the total continental U.S. land area.

Two stretches of the Delaware River, extending 107 miles from Hancock, N.Y. to the Delaware Water Gap, have been included in the National Wild and Scenic Rivers System. The two designated river corridors total 124,929 acres.

As a result of clean-up efforts in the Delaware River, shad and other fish species are increasing in number. A record number of juvenile shad were netted in the Delaware during 1996, a strong indication of exceptionally good spawning runs when these fish return to the river as adults. A recent study of Delaware River shad fishing placed a $3.2 million annual value on this fishery alone.

There are other economic benefits from the river. The Port of Philadelphia, for instance, generated $335 million in business revenue during 1997, according to the Philadelphia Regional Port Authority. State and local taxes from port transactions that year totaled $13 million and there were 3,622 jobs directly stemming from port activities.

The population of the Delaware River Basin increased by 4.5 percent between 1980 and 1990, according to U.S. Census Bureau figures. Large growth spurts occurred in Pennsylvania's Pocono Mountain region and in the Philadelphia suburbs. The basin's population rose by 312,536 over the decade with the 1990 figure standing at roughly 7.3 million people. The basin provides water to another 9.9 million people who live outside the watershed.

Overall, the population of the in-basin portion of Pennsylvania increased by 3.0% over the ten-year span, compared to an increase of only 0.13% for the entire state. The population of Pike County, located in the heart of the Poconos, increased by 53.1 percent compared to a national average growth rate of 10.2 percent. The populations of Monroe and Wayne counties, which flank Pike County, increased by 37.9% and 13.6% respectively. While the City of Philadelphia experienced a population dip of 6.1%, neighboring Chester County grew by 18.7% and Bucks County by 12.9%.

Growth in New York State also occurred at a faster rate within the basin than it did statewide, notching increases of 5.9% and 2.5%, respectively. New Jersey saw a population jump of 6.9% within the basin from 1980 - 1990. Statewide, the population rose by 5.0%. Cape May County was at the top of the chart with a growth rate of 23%.

Only in Delaware did the state growth rate outstrip the in-basin rate (11.9% to 9.6%). Of the state's three counties, Sussex grew the fastest with its population increasing by 20.6% over the period from 1980 to 1990.

The Delaware Bay and tidal reach of the Delaware River have been included in the National Estuary Program, a project set up to protect estuarine systems of national significance. (Roberts, 2000)

2.4.6.5 The National Estuary Program

The purpose of the National Estuary Program (NEP) is to identify, restore and protect nationally significant estuaries in the United States.

There are 28 National Estuary Programs in the nation. Most of these involve one state. Other NEPs that are more than one state include The Lower Columbia River Estuary with Oregon and Washington, The Long Island Sound with New York and Connecticut and, The Harbor Estuary Program with New York and New Jersey.

Two of the National Estuary Programs fall partly or wholly within the State of Delaware. The Inland Bays Estuary Program administered by the Center for the Inland Bays and the Delaware Estuary Program discussed below. A portion of Delaware also drains to the Chesapeake Bay. The Chesapeake Bay program was a forerunner and is not in the National Estuary Program.

In 1996, Delaware Governor Thomas Carper, New Jersey Governor Christie Whitman, Pennsylvania Governor Thomas Ridge and EPA Region III Administrator Michael McCabe approved the *Comprehensive Conservation and Management Plan for the Delaware Estuary* (CCMP).

2.4.6.6 The Delaware Estuary Program

The Delaware Estuary was nominated to join the National Estuary Program in 1988. The Delaware Estuary has wetlands of international importance because they provide food and habitat for birds that migrate from the Southern Hemisphere on their way north every year. As previously mentioned, it is also nationally significant for commerce because it has the world's third largest fresh water port and 1,000,000 barrels of oil are imported up the Bay each day. It contains fisheries and wildlife habitat that are important to the region's economy.

The Delaware Estuary Program is a non-regulatory, voluntary program managed by the States of Delaware, Pennsylvania and New Jersey, the Partnership for the Delaware Estuary, Inc., the Environmental Protection Agency, and the DRBC.

During the development of the CCMP, the following goals and objectives were established:

- Provide for the restoration of living resources of the Delaware Estuary and protect their habitats and ecological relationships for future generations;
- Reduce and control point and nonpoint sources of pollution, particularly toxic pollution and nutrient enrichment, to attain the water quality conditions necessary to support abundant and diverse living resources in the Delaware Estuary;

- Manage water allocations within the Delaware Estuary to protect public water supplies and maintain ecological conditions in the Delaware Estuary for living resources;
- Manage economic growth of the Delaware Estuary in accordance with the goal of restoring and protecting the living resources of the Delaware Estuary;
- Promote greater public understanding of the Delaware Estuary and greater participation in decisions and programs affecting the Delaware Estuary;
- Restore population levels of harvestable species of finfish and invertebrate species to levels that will support sustainable recreational and commercial fisheries;
- Restore or maintain populations of birds dependent on the Delaware estuary to levels deemed attainable by comprehensive analysis;
- Restore or maintain populations of estuarine dependent amphibians, reptiles, and mammals to levels deemed attainable by comprehensive analysis of natural populations;
- Maintain or restore an assemblage of organisms and their habitat throughout the Delaware Estuary and tidal wetlands that a contribute to the ecological diversity, stability, productivity and aesthetic appeal of the region;
- Preserve acreage and enhance quality of shoreline and littoral habitat to sustain a balanced natural system. To restore and maintain the physical and environmental conditions necessary to achieve target levels of estuarine species;
- Restore habitat diversity, values, and functions of tidal and non-tidal wetlands to levels commonly found in the 1920s, done in a balanced consideration of today's socioeconomic needs;
- Assess air quality impacts on estuarine resources and support programs that reduce these impacts;
- Achieve water quality that will maintain and enhance estuarine use designations consistent with the Clean Water Act;
- Optimize sediment quantity and quality in a manner that maintains or enhances a balanced indigenous estuarine biota and habitat;
- Promote and enhance ample and high quality water based and associated terrestrial based recreational opportunities with sustained availability for public use;
- Develop programs and actions that will be mutually beneficial to both the economy and the environment of the estuary, by forging a partnership with industry, commerce, and the local governments in pursuit of continued economic vitality of the region, while enhancing and preserving its living and natural resources;
- Preserve and enhance cultural resources and traditions in the estuary region, and promote their accessibility to the public; and
- Promote pollution prevention technologies and strategies that protect estuarine resources.

The CCMP action plan includes 77 actions plus their related sub-actions for the areas of Land Management, Water Use Management, Habitat and Living Resources, Toxics, Education and Involvement, and Monitoring.

Environmental Indicators

The Estuary extends from the head of tide at Trenton, New Jersey to the mouth of the Delaware Bay and is defined as the area where fresh water from the river mixes with salt water from the sea. To measure progress toward enhancing and preserving this diverse ecosystem, the Delaware Estuary Program has developed an initial suite of nine land and water environmental indicators. Indicators are tools that are used to assess progress toward a goal or objective.

Although the individual indicators range from land use to water quality, many of them are related. For example, an increase in the number of shad (a migratory fish) suggests improved water quality and habitat. The survival of migratory fish is closely tied to dissolved oxygen levels. In the past, pollution caused low dissolved oxygen levels in the heavily industrialized Philadelphia, Camden and Wilmington reach of the river, thus blocking the passage of fish during their migration. Because of improved wastewater treatment and an increased public consciousness about protecting water quality, oxygen levels are much higher and fish passage has significantly improved.

The indicators selected reveal a great deal about the Delaware Estuary region. The areas used for harvesting shellfish have expanded, which suggests improved water quality. People living in the region are using less water due in part to conservation efforts, even though the population is increasing. On the other hand, the Delaware River continues to have significant water quality issues, such as toxins, in the water column and the sediments. Contributing to these contamination concerns are industrial and municipal discharges (i.e., from sewage treatment plants), and nonpoint sources of pollution including stormwater runoff, air deposition, and water dependant activities such as shipping.

The overall message from this initial set of indicators is encouraging, but also illustrates the complexity of the Delaware Estuary. While the water quality and habitat of the Estuary continues to improve, there is plenty of work still to be done to ensure that this progress continues. Collaborative efforts involving regulatory and voluntary actions are necessary to improve the health of the Delaware Estuary. While work continues through the Delaware Estuary Program, citizens can help by keeping trash away from storm drains, recycling used motor oil, participating in river clean-ups, and getting involved in local watershed restoration activities.

2.4.7 DATA GAPS AND RECOMMENDATIONS

1. In consultation with EPA, New Jersey, Pennsylvania, the Partnership for the Delaware Estuary, Inc and other participants should continue to facilitate progress of the DELEP implementation framework.

2. Consider changing the wording in the Delaware Estuary Plan to show that the program is a voluntary and non-regulatory advocate for sustainable development.

3. More sampling sites are needed to monitor the lower estuary.

4. Metals may exceed Delaware Water Quality Standards in the estuary. A comparison of any existing data should be done to determine if criteria are exceeded and if there is a need for the collection of additional data.

5. The State of Delaware should continue to play a major role in cleaning up PCBs and other toxics in the Estuary.

6. Dredging information and management for the Delaware Estuary should be the focus of a Pennsylvania, New Jersey and Delaware Coastal Zone Special Area Management Plan.

7. Explore the concept with Delaware's U.S. Congressional delegation of a permanent funding source for the Delaware Estuary Program.

8. Use Clean Water Act Sections 313 and 316 to review and to update waste-water infrastructure for cooling water. Older technology may be responsible for suppressing fish populations through impingement and entrainment.

9. Poly-Cyclic Aromatic Hydrocarbons should continue to be studied in the estuary to determine if they are responsible for oyster and other fishery problems.

10. The State's DNREC webpage should have more hotlinks to monitoring reports and sites for the estuary.

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2.5 WATER RESOURCES

2.5.1 INTRODUCTION

2.5.1.1 Background

Surface water is that water visible on the earth's surface. It covers nearly 70 percent of the earth's surface and includes oceans, lakes, rivers, streams, and wetlands. Surface water is critical to all life cycles; it houses resources, nutrients, minerals, and energy. It also provides a three dimensional medium for flora and fauna.

Delaware has diverse surface water resources, from faster moving Piedmont streams to slow moving coastal plain streams; the Delaware Bay and Inland Bays estuaries; and many tidal rivers containing fresh or brackish waters. Surface waters support uniquely diverse fish and wildlife populations, provide multiple recreational opportunities, and provide approximately 70 percent of the drinking water supply for New Castle County.

The Delaware Bay and Estuary Basin generally consists of slow moving coastal plain streams although the tidal Delaware River, the Chesapeake and Delaware Canal, and downstream tidal portions of major watersheds are exceptions.

2.5.1.2 Historical Perspective

The progress of mankind has taken its toll on surface water quality. Recent improvements in environmental protection and awareness have helped, but pollution remains a major concern. As recently as 1975, Delaware routinely experienced serious water pollution and public health problems as a result of the discharge of untreated sewage and wastes. Since then, as a result of voluntary efforts, regulatory actions, and significant private and public investments in wastewater treatment facilities, localized improvements in water quality have been achieved.

The need for additional cleanup and pollution prevention continues. The focus of water quality management has shifted from point source discharges (end-of-pipe) to decreased stream flows and nonpoint source problems, such as urban and agricultural runoff, erosion, and sedimentation. Unaddressed, these problems lead to poor habitat conditions for fish and other aquatic life, decreased enjoyment of our surface waters for recreation, and unhealthy conditions for those surface waters upon which we rely for drinking water supply and other domestic uses.

As a result of water quality protection programs that are in place in Delaware, surface water quality has remained fairly stable in spite of increasing development and population growth. Impacts to waters are generally the result of past prac-

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tices or contamination events, activities that are not regulated or otherwise managed, or changes/events that occur on a larger regional scale. For example, air pollutants from sources outside of Delaware may contaminate Delaware's surface waters via rainfall.

Improvements in water quality have been documented in localized areas where a discharge was eliminated or better treatment installed. Basin-wide water quality improvements in waters that are being impacted by historical yet unquantified pollution sources are very difficult to detect over a short period of time. Targeted monitoring over long time periods (years) is necessary in order to detect changes.

Although Delaware's surface water quality may not have changed significantly over the last several years, there have been many improvements made in watershed assessment approaches and methodologies. Additionally, many water quality criteria are stricter as a result of amendments to the State's Water Quality Standards. Therefore, we have become more proficient at identifying water quality problems and, at the same time, are calling for higher quality waters.

The stability of Delaware's surface water quality is likely the result of increased efforts to control both point and nonpoint sources of pollution. In addition to the significant investments in wastewater treatment technologies previously mentioned, many private business interests are investing in practical and cost-effective nonpoint source pollution control practices (Best Management Practices) on farms, residential developments, and commercial and industrial sites. Likewise, public agencies such as the Delaware Department of Transportation are investing revenues in improved stormwater management practices and wetlands creation to mitigate the impacts of maintenance and new highway construction activities.

A detailed assessment, which follows, indicates water quality in the majority of the Basin remains stable, but cautions that phosphorous and bacteria levels are relatively high, causing concern for nutrient over-enrichment and potential health risks to swimmers. In addition, localized increasing nitrogen trends were identified in the Murderkill watershed.

2.5.2 SURFACE WATER

2.5.2.1 Watershed Characteristics

The Delaware Bay and Estuary Basin is defined by sixteen watersheds located along the eastern part of the state. The Basin is narrow at the northern end and broadens through the middle and southern portions of this drainage area (*see Map 1.2-1 Delaware Bay and Estuary Basin Watersheds*). Generally, the surface waters of the basin are well incised in the upper headwaters before reaching the lower, less well-drained portions of the watersheds comprised of tidal marshes along the Delaware Bay and Estuary coastline. The following sections provide descriptions and characteristics of the watersheds in this Basin. Two small area watersheds labeled Delaware River and Delaware Bay, for lack of a named river or tributary in their drainage, are not discussed due to the limited surface water quality information available for these drainage areas.

Appoquinimink River Watershed

The Appoquinimink watershed drains 30,000 acres in southern New Castle County. The headwaters drain mostly agricultural lands and feed four major ponds. The tidal freshwater segment of the Appoquinimink is bound by the head of tide at Noxontown Pond and Silver Lake and by Drawyers Creek's confluence with the Appoquinimink. The remainder of the watershed consists of a tidal marsh extending to the Delaware River. These wetlands are highly valued as waterfowl, shorebird, and wildlife habitat as well as a spawning and nursery area for fish and aquatic life. The major concern in the watershed is nutrient over enrichment; therefore, a phased Total Maximim Daily Load is underway to address this concern.

The watershed is characterized by 69% agriculture, 12% wetland, 11% forested, 3% residential, and 5% other.

Pathogens (as indicated by elevated Enterococcus levels), nutrients, physical habitat condition, and water supply are the main concerns in this watershed.

Army Creek Watershed

The Army Creek watershed drains approximately 6,000 acres in east-central New Castle County. The 4-mile-long mainstem flows east-northeast toward its outfall to the Delaware River just below the town of New Castle. The land uses in the watershed are evenly mixed among agriculture, residential, and commercial. This watershed contains two federal Superfund sites, the Army Creek landfill and the Delaware Sand and Gravel landfill. Concerns in the watershed include low dissolved oxygen levels.

The watershed is charactherized by 37% urban/residential, 30% agriculture, 15% brushland, 9% forests, 8% wetlands, and 1% other.

Pathogens (as indicated by elevated Enterococcus levels), nutrients, physical habitat condition, and water supply are the main concerns.

Blackbird Creek Watershed

The Blackbird Creek watershed drains a portion of southern New Castle County. This is a predominantly rural area, consisting of wetlands, forests, and agricultural lands. Blackbird Creek flows into the Delaware River just upstream from Delaware Bay. Concerns in the watershed include high bacteria counts and low dissolved oxygen levels.

The watershed is characterized by 43% agriculture, 35% forests, 17% wetlands, 4% urban/residential, and 1% other.

Pathogens (as indicated by elevated Enterococcus levels), nutrients, physical habitat condition, and water supply are the main concerns in this watershed.

Broadkill River Watershed

The Broadkill River watershed is located in the east central portion of Sussex County. It is bounded on the north by the Cedar Creek watershed, on the west by the Gravelly Branch and Deep Creek watersheds, on the south by the Lewes-Rehoboth Canal, Rehoboth Bay, and Indian River watersheds, and on the east by the Delaware Bay. The mainstem of the Broadkill River is approximately 25 miles long. The major watercourse in this segment is the Broadkill River which originates at the Town of Milton and discharges into the Roosevelt Inlet near Lewes. Major impoundments in the area are Waggamons Pond and Diamond Pond located near Milton. The Broadkill River flows generally eastward until it approaches the coast where it turns abruptly and flows south to discharge into the Roosevelt Inlet. The flow of this stream is sluggish and the water is turbid. There is only one small incorporated community, the Town of Milton, within the watershed. The primary land uses in the area are agriculture and wildlife refuge. The tidal marshes along the coast are part of a Prime Hook National Wildlife Refuge. The major concerns in the watershed include high nutrient loads, high bacteria counts and low dissolved oxygen levels.

The watershed is characterized by 47% agriculture, 31% forests, 13% wetlands, 5% urban/residential, 3% brushland, and 1% other.

Pathogens (as indicated by elevated Enterococcus levels), nutrients, physical habitat condition, and water supply are the main concerns in watershed.

Chesapeake and Delaware Canal Watershed

The Chesapeake and Delaware Canal (C & D Canal) watershed includes a portion of the Delaware River between Reedy Point and the Appoquinimink River. The C & D Canal is a man-made navigational channel connecting the Delaware River to the Chesapeake Bay. The canal is 450 feet wide and 35 feet deep. The length of the Delaware portion of the canal is 12.2 miles from Reedy Point on the Delaware River to the Delaware-Maryland state line. The land adjacent to the canal, approximately 1,000 feet on the south-side of the canal and 2,000 feet on the north-side, is federal reservation lands currently designated as a wildlife area and previously used by the Corps of Engineers as spoil disposal areas. The prominent drainage tributaries to the canal are Scott Run and Joy Run on the south side of the canal and the Lums Pond State Park on the north side of the canal. The eastern extremity of the canal is low marshland utilized primarily as wildlife habitat. Westward from these low tidal marshes the land rises to a level terrain between 50 to 100 feet in elevation.

Flow and currents in the canal are a function of the differential tidal stages at the two ends of the canal. However, net flow in the canal is from the Chesapeake Bay to the Delaware River. The canal channel penetrates the sands of the Atlantic Coastal Plain and thus intercepts and receives fresh-water discharge from these aquifers.

The C & D Canal watershed is predominantly rural in character. The main communities of population within the watershed are Port Penn on the Delaware River and St. Georges on the canal at the Route 13 bridge crossing. The remainder of the segment is rural.

With the exceptions of the wildlife and tidal marshes and the state park at Lums Pond, the land use in this watershed is still mainly agricultural. Concerns in the watershed include high bacteria counts.

The watershed is characterized by 56% agriculture, 14% forests, 10% wetlands, 9% brushland, 4% urban/residential, 7% other.

Pathogens (as indicated by elevated Enterococcus levels), nutrients, physical habitat condition, and water supply are the main concerns in watershed.

Cedar Creek Watershed

The Cedar Creek watershed is located in the eastern portion of Sussex County. It is bounded on the north by the Mispillion River watershed, on the east by the Delaware Bay, on the south by Broadkill River watershed and on the west by the Gum Branch and Gravelly Branch watersheds. The major watercourse in this watershed is Cedar Creek. Impoundments within this watershed are Cubbage Pond, Clendaniel Pond, and Cedar Creek Mill Pond. Cedar Creek flows in a generally northeasterly direction into a stream called Slaughter Neck Ditch which subsequently flows northward and discharges at the mouth of Mispillion River. Cedar Creek is a tidal stream which flows in a sluggish and meandering manner. The water in this stream is generally turbid. The upland portion of this watershed is generally level to gently sloping and the soils are characterized as having high agricultural productivity. The watershed is sparsely populated with no incorporated communities. There are several population concentrations in mobile home parks and subdivisions. Major land use in the area consists of agricultural lands and tidal marsh and swamp. Concerns in the watershed include low dissolved oxygen levels.

The watershed is characterized by 54% agriculture, 19% forests, 17% wetlands, 8% other, and 2% urban/residential.

Pathogens (as indicated by elevated Enterococcus levels), nutrients, physical habitat condition, and water supply are the main concerns in watershed.

Dragon Run Watershed

The Dragon Run Creek watershed is comprised of over 5,500 acres in eastern New Castle County. The 7.7-mile-long mainstem of the creek rises in a swampy area north of Lums Pond and flows due east to its outfall in the Delaware River. Agriculture is the predominant land use in the basin, although industrial uses are also important. Concerns in the watershed include high bacteria counts.

The watershed is characterized by 48% agriculture, 20% forests, 11% wetlands, 8% urban/residential, and 13% other.

Pathogens (as indicated by elevated Enterococcus levels), nutrients, physical habitat condition, and water supply are the main concerns in watershed.

Leipsic River Watershed

The Leipsic River watershed is located northeast of Dover and is bounded on the southwest by the St. Jones River watershed, on the east by the Delaware Bay and on the north and west by the Smyrna River and Chester River watersheds, respectively. It comprises 63,000 acres of land. Wetlands constitute 36% of the land area. The land of the watershed is generally level to gently sloping. Concerns in the watershed include high bacteria counts and low dissolved oxygen levels.

The watershed is characterized by 43% agriculture, 36% wetlands, 13% forests, 5% other, and 3% urban/residential.

Pathogens (as indicated by elevated Enterococcus levels), nutrients, physical habitat condition, and water supply are the main concerns in watershed.

Little Creek Watershed

The Little Creek watershed is comprised of about 15,000 acres in east-central Kent County. The five-mile-long mainstem of the creek rises east of Dover and flows toward the east through the town of Little Creek to the Delaware Bay. The lower three miles of the creek are saline wetlands. State-owned areas that provide access to water-based recreation include the Little Creek Wildlife Area and the Port Mahon boat ramp. Concerns in the watershed include high bacteria counts and low dissolved oxygen levels.

The watershed is characterized by 47% agriculture, 15% urban/residential, 14% wetlands, 13% forests, and 11% other.

Pathogens (as indicated by elevated Enterococcus levels), nutrients, physical habitat condition, and water supply are the main concerns in watershed.

Misipillion River Watershed

The Mispillion River segment is located in southeastern Kent County and northeastern Sussex County. The Mispillion River flows in a generally easterly direction and forms for its entire length the Kent - Sussex County line. There are four major water bodies in this watershed: Blairs Pond, Griffiths Lake, Haven Lake and Silver Lake. Tidal influences affect the lower Mispillion up to the eastern edge of the City of Milford. The Misipillion Lighthouse is a point located at the mouth of the river. It contains several wharfs used chiefly by fishing party boats and local oystermen. Land in this watershed may be generalized as level to sloping with soils being characterized as having few drainage limitations and being of high agricultural productivity. The two major urban areas are Milford and Houston. Major land use in the area consists of agricultural lands and wetlands. Concerns in the watershed include high nutrient loads and high bacteria counts.

The watershed is characterized by 50% agriculture, 24% forests, 14% wetlands, 5% urban/residential, and 5% other.

Pathogens (as indicated by elevated Enterococcus levels), nutrients, physical habitat condition, and water supply are the main concerns in watershed.

Murderkill River Watershed

The Murderkill River watershed is located in the southeastern portion of Kent County. It is bounded on the south by the Mispillion watershed, on the east by the Delaware Bay, and on the north and west by the St. Jones River and Marshyhope Creek watersheds respectively. It is comprised of 68,000 acres of land. The main watercourse is the Murderkill River with its headwaters just west of Felton. Flowing generally eastward, the length from the headwaters to its mouth on Delaware Bay at Bowers Beach is 20.5 miles. The lower 10.5 miles are tidal. Two important ponds, Coursey Pond and Killens Pond, are both on the Murderkill. Land in this watershed may be classified as dominantly level to gently sloping. Concerns in the watershed include high nutrient loads, high bacteria counts, and low dissolved oxygen levels.

The watershed is characterized by 58% agriculture, 25% forests, 9% wetlands, 6% urban/residential, and 2% other.

Pathogens (as indicated by elevated Enterococcus levels), nutrients, physical habitat condition, and water supply are the main concerns in watershed.

Red Lion Creek Watershed

The Red Lion Watershed is located south of the City of New Castle and north of the Chesapeake and Delaware Canal. The topography is one of level to gently sloping terrain of well-drained soils. The west and central portion of the basin consists of uplands which are productive agricultural land engaged in the production of corn and soy beans. The eastern portion of the segment slopes toward a band of marshland along the Delaware River.

The watershed is characterized by 44% agriculture, 19% urban/residential, 16% forests, 12% brushland, 3% wetland, and 6% other.

Concerns in the watershed include high nutrient loads, high bacteria counts and low dissolved oxygen levels. Pathogens (as indicated by elevated Enterococcus levels), nutrients, physical habitat condition, and water supply are the main concerns in watershed.

St. Jones River Watershed

The St. Jones watershed is located in the central portion of Kent County. It is bounded on the south by the Murderkill River watershed, on the east by the Delaware Bay, on the north and northeast by the Leipsic River and Little Creek watersheds, and on the west by the Choptank River watersheds. It consists of 55,500 acres of land. The major watercourse in the watershed is the St. Jones River which has its headwaters in the western part of the county, about 22 miles upstream from the Delaware Bay. The stream flows in a generally southeasterly direction and is tidal throughout most of the lower half. Within the tidal marsh area, the flow is sluggish and meandering and the water turbid. Significant ponds in the watershed are Silver Lake, Moores Lake, and Wyoming Lake. The area is generally level to gently sloping, and the soils are characterized as having high to very high agricultural productivity. The St. Jones watershed is the most populated watershed in Kent County.

The watershed is characterized by 53% agriculture, 20% forests, 20% wetlands, 17% urban/residential, and 3% other.

Concerns in the watershed include toxics, high nutrient loads, high bacteria counts and low dissolved oxygen levels. Pathogens (as indicated by elevated Enterococcus levels), nutrients, physical habitat condition, and water supply are the main concerns in watershed.

Smyrna River Watershed

The Smyrna River watershed, located in the northeastern corner of Kent County, is bounded on the west and south by the Chester River and Leipsic River watersheds respectively, on the east by Delaware Bay and to the north by the Appoquinimink River watershed. This watershed extends north into New Castle County. The major water course is the Smyrna River which forms part of Kent County's northern boundary and New Castle County's southern boundary. The Smyrna River generally flows in a northeasterly direction. The lower ten miles are tidal. The land area of this segment totals approximately 19,000 acres. Land use is mostly agricultural. There are two incorporated areas in the watershed, Smyrna and Clayton.

The watershed is characterized by 55 % agriculture, 27% forests, 10% wetlands, 4% urban/residential, and 4% other.

Concerns in the watershed include high nutrient loads, high bacteria counts, and low dissolved oxygen levels. Pathogens (as indicated by elevated Enterococcus levels), nutrients, physical habitat condition, and water supply are the main concerns in watershed.

2.5.2.2 Water Quality

The preliminary assessment of water quality data for the Delaware Bay and Estuary Basin within Delaware has been done. The study used statistical methods to assess the chemical and physical water quality data collected through the State's ambient surface water quality monitoring program.

The assessment analyzed data from at least 85 sampling locations distributed along the entire basin from north to south in each watershed, some located in the bay and estuary (*see Map 2.5-1 Surface Water Monitoring Locations*). These data included general chemical and physical parameters, bacteria, and nutrients, and were retrieved mainly from the EPA's STORET (STOrage and RETrieval) system. As these data had censored values, outliers, multiple observations within a time interval, as well as the common problems when data are retrieved and converted from one type to another type, they were manipulated and treated before applying statistical methods on them.

Mean, median, standard deviation, maximum and minimum statistical parameters were used to characterize the existing condition. In addition, excursion analysis applied to parameters that had applicable numerical limits stated in the State of Delaware Surface Water Quality Standards or the EPA Quality Criteria for Water. Trend analysis (Mann-Kendall and Seasonal Kendall nonparametric methods) was used to characterize the changes of the water quality condition. The analysis applied these methods to the data to test the statistical significance of apparent changes in concentration over time and, at the same time, estimated the magnitudes of the changes.

Results from the analysis showed major concerns related to the following parameters, as their concentration levels were frequently found above acceptable water quality criteria limits:

- *Enterococcus* bacteria: Concentrations frequently exceeded the fresh water quality standard of 100#/100 ml in a number of places, mainly, along the tributaries.
- Total phosphorus: Excessive concentrations (average above 0.1 mg/l, 0.05 mg/l, or 0.025 mg/l) support the concern of nutrient enrichment in the Basin.
- Dissolved oxygen: Concentration exceeded the standard (5.5 mg/l for June to September and 4.0 mg/l as a minimum) quite frequently in a majority of the tributaries within the basin.
- pH: With the exception of values measured for the C & D Canal, pH values consistently fell outside the acceptable range of 6.5 standard unit - 8.5 standard unit.

Trend analysis showed that, collectively, no parameter had an obvious change throughout the Basin. Although there were instances where changes were detected at several locations, the magnitude and spacial coverage of the changes were not large enough to indicate significant change in water quality. Therefore, the study indicates that water quality in the Delaware Bay and Estuary Basin has remained stable.

Eutrophication

With increasing concerns over eutrophication in the Basin, several nutrient species have been analyzed for status and trend. These findings are described in the following section.

Phosphorus (Total Phosphorus)

Concern about phosphorus content in streams is based primarily on the role of phosphorus in promoting eutrophication. Among the major nutrients, phosphorus is most likely to limit plant growth in freshwater streams. This is the case in the Delaware Bay and Estuary Basin as manifested by nitrogen/phosphorus (N/P) ratio analysis discussed later in this section. Despite the strong correlation that exists between total phosphorus concentrations and the degree of eutrophication, a water quality standard for phosphorus in streams has yet to be developed. However, the EPA's "Quality Criteria for Water" suggests upper limits of total phosphorus for the prevention of nuisance growth. The criteria are 0.05 mg/l at the point where a stream enters a lake, 0.025 mg/l within a lake, and 0.1 mg/l in streams not flowing directly into lakes.

Excursion analysis of 1992-1996 records showed that total phosphorus exceeded the limits frequently (>25 percent of the time) throughout most of the Basin. The high exceedance suggests possible eutrophy existence in the Basin.

As discussed above, trend analysis suggests that total phosphorus has remained stable in the Basin. A few areas showed concentration changes, but the affected spacial coverage was too small to indicate a watershed-wide change in phosphorus level trends.

N/P ratios were calculated for each station to determine whether the limiting nutrient in the eutrophication process was phosphorus or nitrogen. Generally, a ratio above 10 indicates that phosphorus is the limiting nutrient, while a ratio below 10 indicates nitrogen as the limiting nutrient. N/P ratios throughout most the Basin were well above 10, thereby indicating that phosphorus is the limiting nutrient in the eutrophication process in the Basin. Only a few places throughout the Basin had N/P ratios of less than 10. *Map 2.5-2 Total Phosphorus Concentrations and Trends* shows the sampled locations and associated data.

Nitrogen

Total Nitrogen

Total nitrogen concentrations were calculated by adding up concentrations of Total Kjeldahl Nitrogen (TKN) and nitrate-nitrite nitrogen. Mean and median concentrations of total nitrogen were in the range of 1.13 mg/l - 6.72 mg/l. Trend analysis was not informative for this parameter.

Total Kjeldahl Nitrogen (TKN)

Total Kjeldahl Nitrogen, which represents the combined concentrations of ammonia and organic nitrogen, is another water quality indicator. A review of the current data showed that TKN concentrations were relatively uniform in the Basin. Between 1970 and 1996, decreasing trends were detected at several locations.

Nitrate-Nitrogen (NO_3 - N)

Nitrate-nitrogen and nitrite-nitrogen are the two highly bioavailable sources of nitrogen for phytoplankton growth. Generally, nitrate-nitrogen concentrations are much higher than nitrite nitrogen, thus, contributing more to phytoplankton growth.

(Many stations did not provide separate measures of nitrate-nitrogen and nitrite-nitrogen, but, rather, combined the two. See the following discussion on Nitrate-Nitrite Nitrogen.)

Nitrite-Nitrogen (NO_2 - N)

See discussion in Nitrate-Nitrite Nitrogen part.

Nitrite-Nitrate Nitrogen (NO_2 + NO_3 - N)

Average concentrations of nitrite-nitrate nitrogen in the Basin ranged from 0.25 mg/l to 5.96 mg/l. Trend analysis shows that there exists stream reaches within the basin which continue to generate increasing or sustained nitrate-nitrite nitrogen loads. These locations are shown on *Map 2.5-3 Total Nitrogen Concentrations and Trends*.

Total Ammonia Nitrogen

Ammonia nitrogen, which exists in waters as ammonia (NH_3) or as ammonium-ion (NH_4^+), is an indicator of organic pollution. The ammonia (NH_3) form is toxic to fish, and toxicity varies with the pH of stream water. USEPA recommends 0.02 mg/l of NH_3 as a criterion to protect freshwater aquatic life.

Average concentration of ammonia nitrogen ranged from 0.019 mg/l to 0.563 mg/l. Decreasing trends were detected at several locations.

Dissolved Oxygen (DO)

Dissolved oxygen is the most essential measure of stream water quality. The State of Delaware Surface Water Quality Standards indicates that daily average concentration of DO should not be less than 5.5 mg/l in June - September, and minimum concentration of DO should not be less than 4.0 mg/l for supporting aquatic life.

Overall, DO levels were acceptable during 1992 - 1996. The mean and median concentrations of DO were generally above 5.5 mg/l. Excursion analysis showed water quality met the standards throughout most of the Basin. Only a few spots had data values that exceeded standards more than 25 percent of the time. During the same time, mean and/or median concentrations at these locations were below 5.5 mg/l. The occurrences of the exceedance were frequent enough to indicate that dissolved oxygen was not adequate to support aquatic life in many locations. Other than in the C & D Canal watershed, every other watershed within the basin has segments which fail to provide aquatic life support because of dissolved oxygen fluctuations.

Trend analysis indicated that the concentrations of DO were varied in the Basin. The detected changes over recent years were not significant enough to suggest a Basin-wide change in level trends. *Map 2.5-4 Dissolved Oxygen Concentrations and Trends* shows the sampled locations.

Chlorophyll-a

Chlorophyll-a concentrations were high (>38 ug/l) in the Appoquinimink near Odessa, in Drawyers Creek, and Noxontown Pond. In the Broadkill, Lower Red Mill Branch, Red Mill Pond, and the lower Broadkill all averaged in exceedingly. Others exceeding: Lower Cedar Creek, Garrison's Lake, Lower Little Creek, Lower Misipillion River, Mid-Murderkill River, Killens Pond, the Upper and Lower St. Jones River, Silver Lake, the Smyrna River and Mill Creek. Over time, no trend has been detected.

Bacteria

The state water quality standard for primary contact recreation in fresh water is based on the geometric average of *enterococcus* bacteria. This average shall not exceed 100 colonies per 100 ml under conditions characterized by the absence of rainfall-induced runoff. As no such rainfall data was available along with water quality data, the analyses were performed without considering the rainfall-induced situation. Primary contact recreation is the designated use for all streams in the Basin except for the C & D Canal.

Evaluation of historical data demonstrated that *enterococcus* bacteria concentrations violated the standard in a number of places. More than 60% of the basin cannot meet the bacteria standard.

Trend analysis indicated that concentrations of *enterococcus* bacteria in the Basin were mostly increasing using the geometric mean. Although there are a few stream reaches that have improved, the increases in others, especially ponds and lakes are significant.

Other

Total Suspended Solids

Total suspended solids measures the impurities that may cause murkiness, turbidity, odor, color, and even disease. High solids content may also indicate high phosphorus concentrations that, in turn, promote eutrophic conditions. Examination of historical data showed that total suspended solids concentrations in lower reaches of streams were three to four times higher than in upper reaches and their tributaries.

Overall concentrations were stable throughout the Basin. No significant changes were noticed in the main stream of the watersheds. However, this does not dismiss the slight rises due to increased anthropogenic disturbances.

Total Hardness

Total hardness is an important parameter for drinking waters. Water supplies are classified as soft, moderately hard, hard, or very hard based on the following total hardness values:

Total Hardness (as $CaCO_3$ in mg/l)	Classification
0 – 75	soft
75 – 150	moderately hard
150 – 300	hard
300 and up	very hard

Historical data show that water in the Basin has been soft. Total hardness concentrations were all below 75 mg/l, except one station at Summit Bridge on the C & D Canal, where total hardness had a mean 500 mg/l and median 264 mg/l. No significant trends were noticed in the Basin.

pH

The State's surface water quality standard requires that fresh water pH levels to range between 6.5 to 8.5 standard unit (su). Although the mean and median were within this range for most of the Basin, the excursion analysis indicated that data points fell outside the range (below 6.5 su in most cases) quite frequently over wide areas of the Basin. Over time, no significant changes in pH trends (in water quality perspective) have been identified.

Water Temperature

Water temperatures were relatively uniformly distributed throughout the Basin (i.e., around 13°C, but with noticeable variability between seasons). The lowest temperatures were 0°C recorded during the winter, while the highest was 31.5°C recorded in the summer. Over time, no changes have been identified for this trend.

Total Alkalinity

The Quality Criteria for Water has recommended 20 mg/l or more as $CaCO_3$ for freshwater aquatic life, except where natural concentrations are less. In the Basin, the mean and median concentrations of alkalinity were around 20 mg/l. Only a few places had lower concentrations of roughly 10 mg/l. These data indicate that Basin water has sufficient buffering capacity. No obvious change to this trend was observed over time for most of the Basin.

Biological Assessment of Nontidal Streams

Biological and physical habitat data have been collected in Delaware since 1990 and have been used in the Section 305(b) reports issued biannually. These data are currently being compiled in portions of the state. The biological assessments are based upon aquatic macroinvertebrates, including the aquatic forms of insects, crayfish, worms, and snails. Physical habitat assessments are based upon visual measurements of the stream channel, banks, shade, and the riparian zone.

Total Maximum Daily Load

Federal Clean Water Act Requirements

Section 303(d) of the 1972 Federal Clean Water Act (CWA), as amended, requires states to develop a list of waterbodies that need additional pollution reduction beyond that provided by the application of existing conventional controls. These waters are referred to as "Water Quality Limited" and must be periodically identified by the Department of Natural Resources and Environmental Control (DNREC) or the federal Environmental Protection Agency (EPA).

Water Quality Limited waters requiring the application of Total Maximum Daily Loads (TMDL) are identified in a document commonly referred to as the "303(d) list." A TMDL is the level of pollution or pollutant load below which a waterbody will meet water quality standards and thereby allow use goals such as drinking water supply, swimming and fishing, or shellfish harvesting to be achieved. A state's 303(d) list must be reviewed and approved by EPA by April 1st of every even-numbered year.

A full TMDL process determines the pollutants causing water quality impairments, identifies maximum permissible loading capacities for the waterbody in question, and, for each relevant pollutant, assigns load allocations--Total Maximum Daily Loads--to each of the different sources, point and nonpoint, in the watershed.

The full TMDL process is an effective and important tool for achieving water quality standards, but is time-consuming and labor-intensive. For this reason, TMDLs are currently pursued for high priority waters with the most severe water quality problems including the Appoquinimink River and the Murderkill River in this Basin (also to date, the Inland Bays and Nanticoke watersheds statewide). These waters are typically impacted by both point sources (e.g., sewage treatment plants, industrial facilities) and nonpoint sources (e.g., stormwater runoff from urban and agricultural lands).

The CWA mandates that EPA perform all of the responsibilities not adequately addressed by a state. To date, scores of Section 303 lawsuits across the county have been filed against EPA. Plaintiffs have prevailed in most of those cases resulting in court-ordered TMDL development schedules as short as five years.

Citizen Groups Sue EPA Over Delaware Water Quality

In August, 1996, James R. May, Esq., Director of the Environmental Law Clinic at Widener University School of Law, on behalf of the American Littoral Society (and its affiliate, Delaware River Keeper Network) and the Sierra Club, filed a federal complaint. This complaint charged the U.S. EPA with "the failure to perform its mandatory duties to identify and then to improve the water quality of hundreds of miles of rivers, streams, and Atlantic coastline, and thousands of acres of lakes, reservoirs, ponds, bays, estuaries, and wetlands in the State of Delaware which fail to meet the fishable and swimmable water quality standard as required by the Federal Water Pollution Control Act, 33 U.S.C. §1251 *et seq.* (1988) commonly known as the Clean Water Act." (*American Littoral Society, et al. v. United States Environmental Protection Agency, et al.*; Civil Action No. 96-5920)

The Complaint asks the Court to order EPA to:

- Comply with CWA requirements for TMDLs in Delaware on a short time line.
- Commit to updating Delaware's Continuing Planning Process which serves as the overall framework for water resources management in the State.
- Not issue or approve any new or renewed National Pollutant Discharge Elimination System (NPDES) permits discharging into impaired waters for which TMDLs or TMDTLs (Total Maximum Daily Temperature Loads) have not been established.
- Cease any additional grant funding to Delaware to administer the 303(d) program until the State's 303(d) list meets the requirements of the CWA.
- Administer the NPDES program for Delaware until the State has an EPA approved CPP in place.

DNREC agreed to be present during a federally funded mediation process and assist EPA with program and technical issues. A settlement was reached and the Department's Secretary and EPA's Regional Administrator signed an interagency Memorandum of Understanding (MOU) dated July 25, 1997.

Delaware's Total Maximum Daily Load Program

Since the early 1990s, EPA has urged states to adopt a watershed approach to water quality management. EPA issued a new TMDL guidance document in 1991 encouraging the development of TMDLs on a watershed basis. Delaware has implemented a watershed approach that includes the integration of the TMDL monitoring and assessment program for each watershed in accordance with DNREC's Whole Basin Management Program schedule.

Settlement Negotiations

Plaintiffs demanded an accelerated schedule to ensure that TMDLs for all 1996-listed waters will be established by 2006. DNREC and EPA agreed to a schedule for completion of the TMDLs on a 10-year schedule.

Included in the settlement with EPA, and in addition to the commitment to a 10-year schedule for TMDL development in Delaware, are commitments to prepare a supplement to Delaware's 1996 List of Impaired Waters to include waters impacted by habitat degradation from agricultural and urban activities, develop guidance documents regarding the use of biological and habitat data for listing waters in 1998, and develop protocols for assessing wetlands in Delaware. The MOU between EPA and DNREC sets forth the duties of EPA and DNREC that will serve as the framework for administering the TMDL program in Delaware.

Current TMDL activities in the Delaware Bay and Estuary Basin

The Appoquinimink River and Murderkill River have been identified as water-quality-limited waters, included in Delaware's 1996 and 1998 303(d) list, and were targeted for development of TMDLs. The major environmental problems in these waters are nutrient overenrichment and low dissolved oxygen levels caused by point source discharges and nonpoint sources.

Future Pollution Management Activities

Once a TMDL is promulgated, a Pollution Control Strategy (PCS) will be developed. A PCS will specify the necessary pollutant load reductions that need to occur such that loadings will be less than or equal to the TMDL. Plans are for reductions to be achieved through voluntary (for those activities that are voluntary now) and regulatory (for those activities that are regulated now) actions. However, TMDLs will provide watershed-wide pollution reduction targets which DNREC (and EPA) will be legally obligated to meet. This obligation will require new approaches for addressing point and nonpoint sources of pollution. Concepts such as "pollution trading" between different sources of pollution, geographic targeting, and pollution prevention will all be considered as part of the PCS. Meeting these targets may require regulation under existing law.

2.5.2.3 Quantity

Streams in the Delaware Estuary Basin receive most of their water as base flow from ground water. This ground water, along with normal precipitation, provides an abundant water supply during all but most severe drought. However, localized water-quantity problems can arise if the resource is not properly managed. For instance, many of the small streams in the Basin are used as sources of irrigation water. As long as stream flow is normal or above, this use does not create a problem. If stream flow drops substantially below normal, then these small streams may suffer from habitat degradation or loss.

Stream-Flow Measurements

Over the years, the United States Geological Survey (USGS) has installed stream gaging stations on several free flowing streams within the Delaware Estuary Basin to measure daily flows and study long-term changes in flow patterns. *Table 2.5-1* lists the watersheds within the Delaware Estuary Basin which have USGS gaging stations, the period of record at each station, as well the latitude and longitude for the location of station. Daily streams flows during the year 2000 for three stream gaging stations (station 1483153 on the Appoquinimink River at Noxontown Lake outlet near Middletown, station 1483200 on the Blackbird Creek at Blackbird Station Road, and station 1483700 on the St Jones River at Dover) are shown in *Figure 2.5-1*.

Table 2.5-1 Streams with USGS Gaging Stations

Station ID	Site Name and Location	Watershed	Period of Record	Lat.	Long.
1482200	Army Creek at State Road	Army Creek	7/19/1978 9/30/1981	39°38’56”	75°37’18”
1482298	Red Lion Creek at Red Lion Road	Red Lion	8/4/1978 9/30/1981	39°36’16”	75°40’06”
1483153	Noxontown Lake outlet near Middletown	Appoquinimink River	10/1/1992 Present	39°26’00.4”	75°40’59.8”
1483170	Dove Nest Branch near Odessa	Appoquinimink River	9/6/1978 9/30/1980	39°27’45.4”	75°41’15.8”
1483200	Blackbird Creek at Blackbird Station Road	Blackbird Creek	10/1/1956 Present	39°21’58.6”	75°40’09.8”
1483500	Leipsic River near Cheswold	Leipsic River	7/1/1931 9/30/1957	39°13’58”	75°37’57”
1483670	Mudstone Branch at Chestnut Grove	St Jones River	10/1/1992 9/30/1994	39°10’37”	75°34’55”
1483700	St Jones River at Dover	St Jones River	1/1/1958 present	39°09’49.4”	75°31’08.7”
1484000	Murderkill River near Felton	Murderkill River	7/1/1931 9/30/1999	38°58’33”	75°34’03”
1484100	Beaverdam Branch at Houston	Misspillion River	5/1/1958 9/30/2001	38°54’20.8”	75°30’45.9”
1484270	Beaverdam Creek near Milton	Broadkill River	5/1/1971 9/30/1980	38°45’41”	75°16’03”
1484300	Sowbridge Branch near Milton	Cedar Creek	10/1/1956 9/30/1978	38°48’51”	75°19’39”

Tidal Elevation

Delaware Estuary and tidal rivers within the Basin are under tidal influence. Tidal elevations and currents at several locations along Delaware Estuary and its tidal rivers are monitored by various State and Federal agencies including the Delaware Geological Survey, the US Geological Survey, and the National Ocean Service, NOAA. Tidal oscillations during January 1, 2002 to January 15, 2002 at Delaware City and Reedy Point are shown in *Figure 2.5-2*.

2.5.3 GROUND WATER

Ground water is defined as the subsurface water that occurs beneath the water table in soils and geologic formations that are fully saturated. Ground-water studies, however, must include recognition of subsurface water found above the water table, termed the unsaturated (or vadose) zone, and of surface-water bodies. All three are tightly interrelated as part of the entire hydrologic cycle.

2.5.3.1 Use

Ground water is both an important environmental and economic resource throughout the Delaware Bay and Estuary Basin because of its role in providing base flow to streams and wetlands (particularly important during times of low rainfall and drought), and as a source of water supply for domestic, public, industrial, and agricultural users. In all portions of the Delaware Bay and Estuary Basin, ground water provides a vital supply of base flow to all streams and rivers. In the Basin, base flow contributes between 60 to 80 percent of the total non-tidal stream flow (Johnston, 1976). Furthermore, except in areas above the Chesapeake and Delaware Canal, ground water is the sole source of drinking water and provides the majority of water for all other uses in the Delaware Bay and Estuary Basin.

2.5.3.2 Characteristics

As discussed in Section 2.1 (Geology, Hydrology and Soils), the entire Delaware Bay and Estuary Basin is in the Atlantic Coastal Plain physiographic province. Delaware’s Coastal Plain is a layer cake of interbedded sand, silt, and clay that thickens as it dips to the southeast. The reader is directed to

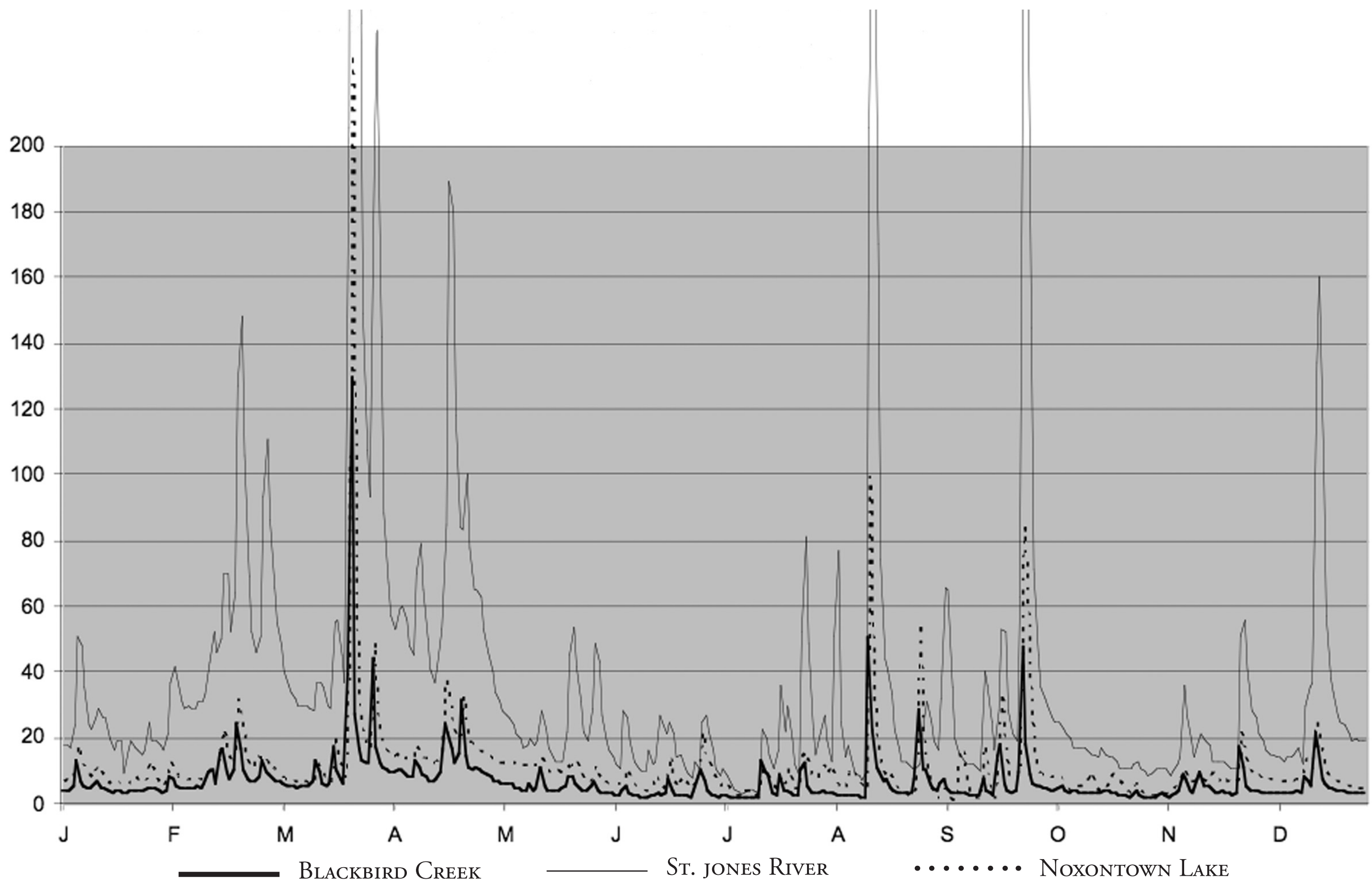

Figure 2.5-1 Stream Flows at Several Gaging Stations (January-December 2000)

Section 2.1 for a more detailed description of the geology. This geology and the relatively high local precipitation of over 40 inches per year create an environment where ground water occurs at relatively shallow depths beneath the land surface throughout the Basin (*see Map 2.5-5 Water Table Elevation*). And, as detailed in the Geology Section, useable ground water can also be found at significant depths beneath the Basin.

The same factors that make the Delaware Bay and Estuary Basin's ground water easily accessible and plentiful can also lead to easier contamination from numerous land-use practices. Most of the soils in the Basin are very permeable, which enables the rapid transfer of surface contaminants into the unconfined (water table) aquifer. *Map 2.5-6 Water Resource Protection Areas* shows the extent of the areas with high ground-water recharge potential where rain and surface water can very rapidly enter the water table. In addition, many of the subsurface sediments are also quite permeable and can facilitate further migration of contaminants through the aquifer towards discharge locations (wells, streams, etc.).

For the purposes of ground-water quality analysis, the resource must be further divided into unconfined and confined aquifers. In general, the unconfined, or water table, aquifer is more susceptible to anthropogenic contamination than are the deeper confined aquifers. This means that surface and near-surface land use practices can more easily and more rapidly impact water quality in the unconfined aquifer. Contamination of the deeper aquifers is usually slower and, in most cases, is caused by localized, site specific problems or practices. Although the water-table aquifer is more vulnerable to contamination, its accessibility, relatively high yield, and useable thickness make it the most highly utilized aquifer in the Basin for both potable and non-potable water. Section 2.3 details known and potential contaminant sources that can impact ground-water quality and, consequently, ground-water availability.

In this section, ground-water quality and quantity data are reviewed, and general conclusions about the resource are made. It is important to note that, in most cases, ground-water data by its very nature are a biased dataset. The water is extracted from wells that were often installed for specific purposes (domestic water use, contaminant monitoring, etc.) and is only a snapshot of the resource as a whole.

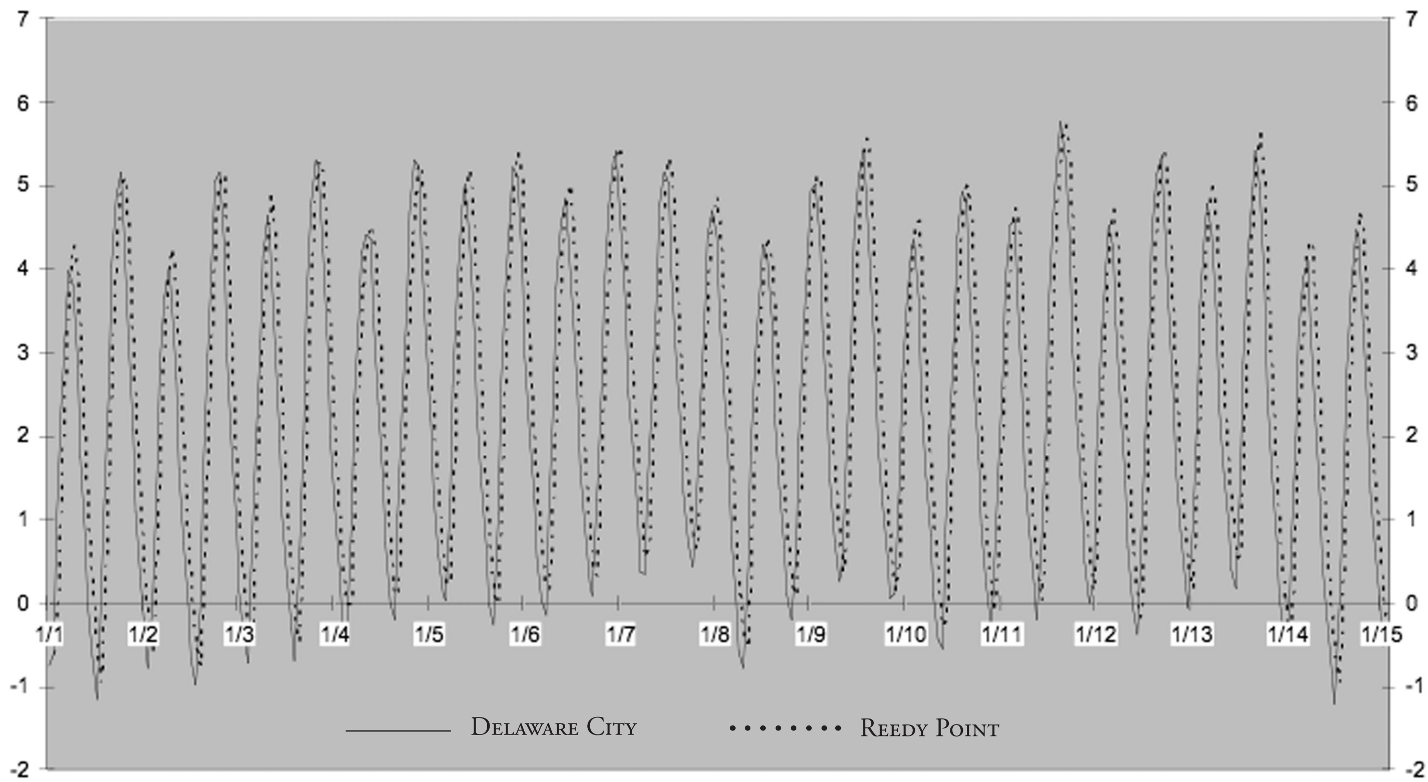

Figure 2.5-2 Tidal Elevations at Delaware City and Reedy Point (January 1 to January 15, 2003)

2.5.3.3 Quality

Nutrients

As discussed in Section 2.3, many different land-use practices can introduce nutrients as a contaminant into the subsurface. The following is a brief summary of the nutrient-related findings associated with the data collection for this assessment.

Nitrate

Map 2.5-7 Nitrate Concentrations in Selected Wells shows the wells for which the Department has Nitrate-Nitrogen data. Because of resource constraints, most of this information comes from wells that were installed for reasons other than ambient water-quality measurements. The map ranks average nitrate concentration (as dot color) and shows the average and maximum concentrations along with the total number of samples for each well. These data come from numerous sources as indicated in the map legend.

The lower nitrate concentrations in the northern half of the Basin are indicative of the reliance on deeper confined aquifers in these areas. Conversely, more elevated nitrate concentrations in the southern half of the Basin represent a more extensive use of the surficial aquifer.

Very little information is known about the average water quality of the numerous domestic wells in the more rural areas throughout the Basin. Although estimates have been made that almost 20 percent of the population of southern Kent and Sussex County have domestic well water with nitrate concentrations exceeding 10 mg/L, location-specific water quality is not well defined.

The lack of data for much of the more rural areas does not mean that there is no concern, but rather shows the limitation of the Department's ability to assess the ground water in those areas with existing resources. To get an idea of the potential impact, compare *Map 2.5-7 Nitrate Concentrations in Selected Wells* and *Map 2.5-8 Domestic Well Densities* to identify areas where there is significant ground-water use with little information about the water quality. For instance, the areas surrounding towns and cities (e.g., north of Middletown, south and west of Smyrna, south of Dover, west of Lewes) show relatively high domestic well densities with little or no ground-water quality data.

Further information is required to truly understand Basinwide nitrate contamination trends. The lack of water quality data for large portions of the Basin shows the need to incorporate all possible water quality analyses into an "ambient" monitoring network. More effort should be made by the various programs and agencies to cooperate on future data collection and distribution.

Phosphorus

There are very few locations in the Delaware Bay and Estuary Basin where phosphorus data have been collected for ground water. The reason for the lack of data is that most of the ground-water monitoring locations have not been sampled for phosphorus. Phosphorus is not regulated under the Safe Drinking Water Act and therefore is not a required analyte in the Public Water Supply (PWS) wells. Furthermore, phosphorus is often bound in the soil matrix and is usually not a major concern in ground water. Much more work and monitoring needs to be done if more information is to be obtained on phosphorus levels in ground water.

Chemicals

Section 2.3 discusses the many different chemical sources that can introduce contaminants into the subsurface. This problem occurs as a result of spills, leaks, land-use practices, and permitted discharges. The following is a brief summary of specific chemical-related findings associated with the data collection for this assessment.

Chloride

Map 2.5-9 Chloride Concentrations in Selected Wells shows wells for which the Department has chloride data. Chloride contamination comes primarily from three sources: road salt application, direct discharge, and natural salt-water intrusion. The first two sources are anthropogenic while the third is completely natural. However, natural salt-water intrusion can be exacerbated by human practices (e.g., dredging, channeling, over-pumped wells, etc.). Because of resource constraints, most of this information comes from wells that were installed for reasons other than ambient water quality measurements. The map ranks average chloride concentration (as dot color) and shows the average and maximum concentrations along with the total number of samples for each well. These data come from numerous sources as indicated in the map legend.

A review of *Map 2.5-9 Chloride Concentrations in Selected Wells* shows that, even though the data are sparse, chlorides in ground water are not a major concern in the Basin. There are isolated areas where elevated chloride concentrations have been detected, but most of the data show levels near background. The only exception is the public well near Clayton/Smyrna.

Although the wells do not adequately cover the entire Basin, with the exception of the Clayton/Smyrna well, the average chloride concentrations of wells throughout the Basin do not exceed the secondary drinking-water standard of 250 mg/L.

Iron

Map 2.5-10 Iron Concentrations in Selected Wells shows the wells for which the Department has iron data. Iron contamination can come from human sources like salvage yards and industrial facilities, but is also a commonly occurring natural contaminant. Additionally, many of Delaware's aquifers have significant levels of iron in the formation and, therefore, in the water. Iron contamination is mainly an aesthetic concern with regard to taste and water color, but the EPA has also established a secondary MCL of 0.3 mg/L for human consumption. Because of resource constraints, most of this information comes from wells that were installed for reasons other than ambient water quality measurements. The map ranks average iron concentration (as dot color) and shows the average and maximum concentrations along with the total number of samples for each well. These data come from numerous sources as indicated in the map legend.

Map 2.5-10 Iron Concentrations in Selected Wells shows that numerous wells in the Delaware Bay and Estuary Basin have average iron concentration in exceedance of the 0.3 mg/L seconadry MCL. The water from the public supply wells may be diluted to levels below the drinking water standard prior to consumption, but the Safe Drinking Water Act does not require water suppliers to do so.

Pesticides

Because a large portion of Delaware is devoted to agriculture, there is a significant chance of agricultural chemicals and by-products entering the subsurface as contaminants. Fertilizers contribute vital nutrients to the state's many crops, but, when not used wisely, can also contribute to ground-water pollution. In order to compete in the global economy, many of Delaware's farmers also use pesticides (herbicides, insecticides, fungicides, etc.) for better crop management. Such use can lead to these compounds contaminating various resources, like ground water.

The Delaware Department of Agriculture (DDA) has developed a statewide pesticide-monitoring network to test for these chemicals in ground water. The network consists of over 100 shallow wells, selected somewhat randomly, throughout the state. The DDA and DGS released a joint investigative report that summarizes the occurrence and distribution of pecticides in shallow ground water. This report, released in 2000, provides pesticide results from water samples collected over a three-year period from 1995 through 1998 (Blaier and Baxter, 2000).

Ground-Water Quality Conclusions

Besides naturally occurring iron, nitrate appears to be the main contaminant of concern in ground water throughout the Basin. Serious concerns for other contaminants may exist on a localized, site specific basis. Overall, the Delaware Bay and

Estuary Basin is impacted by elevated nitrate levels more than by any other contaminant.

2.5.3.4 Quantity

Well Density Maps

A series of maps, generated for this assessment, depicts various categories of water supply wells found throughout the Delaware Bay and Estuary Basin. Categories include Domestic (*Map 2.5-8 Domestic Well Densities*), Public (*Map 2.5-11 Public Water Supply Well Locations*), Industrial (*Map 2.5-12 Industrial Well Densities*), and Irrigation wells (*Map 2.5-13 Irrigation Well Densities*), and are based on well-permitting data. With the exception of *Map 2.5-11 Public Water Supply Well Locations*, which shows the general well locations, each of the other categories of wells is depicted on separate maps as "densities" using a graduated chromatic scale corresponding to numbers of wells of specific types existing within modified-grid area polygons. Some limited well attributes are included on the maps, such as the well counts for modified grids.

A composite map (*Map 2.5-14 Combined Well Densities*) shows the above categories of wells, in addition to monitoring wells, in point-coverage format. The point-coverage well locations are not the exact locations. Rather, the locations are roughly evenly distributed within the modified-grid area.

The monitoring wells plotted on the composite map are also in roughly even distribution within modified grids, and were included to indicate locations where ground-water quality is under investigation. Typical monitoring well installations are for evaluating underground storage tanks, community wastewater disposal systems, landfills, and even Superfund sites. Thus, areas with monitoring wells could be indicators of potential sources of contamination to water supply wells. This assessment technique is very generic, and site-specific information must be obtained for an area of interest to determine the existence or extent of any contamination problems. Refer to Section 2.3 for a discussion on the known and potential contaminant sources found within the Basin.

Completing the map series is a map representing ground-water usage as a maximum-daily withdrawal rate within each modified-grid (also in a graduated chromatic scale). This map is based on the "Maximum Daily Use" as estimated at the time the original well construction permit was applied for, and, therefore, does not represent actual usage (*Map 2.5-15 Maximum Daily Ground-Water Use*).

Interpretation

Some observations can be made on the occurrence and distribution of the various wells. As seen in the composite density map, most wells are concentrated in and around municipalities, corresponding to traditional development and land use patterns. Throughout the Basin, domestic supply wells are, in general, fairly evenly distributed in the rural areas, with industrial wells located near and within towns. A divergence from this pattern is seen in the middle of the Basin south of Dover and Milford, and west of Lewes, where there is a predominance of domestic wells.

Irrigation wells are generally associated with major farming operations, which widely employ irrigation systems, and to a lesser extent with privately-owned farms. It is evident that while agricultural activity exists throughout the Basin, the most intensive activity occurs in the southern half from Dover to Milton in the Leipsic River, St. Jones River, Murderkill River, Mispillion River, Cedar creek, and Broadkill River watersheds.

Clusters of monitoring wells can be easily connected to known ground-water contamination sites, such as in the northern part of the Basin surrounding the Delaware City industrial complex. A high density of monitor wells also exists south of Dover affiliated with the Dover Air Force Base.

Areas of large ground-water withdrawals (as shown *Map 2.5-15 Maximum Daily Ground-Water Use*) correspond most closely with the presence of irrigation wells. There is less of a relationship between numbers of irrigation wells within a modified-grid and the intensity of irrigation withdrawals, as only a minority of the areas with the highest number of irrigation wells also have the highest rate of usage. This relationship may indicate geologic variation that affects ground-water availability, as wells as, other factors related to actual farming operations.

2.5.4 DATA GAPS AND RECOMMENDATIONS

1. Because of the nature of the sampled media, it is often quite difficult to adequately sample ground water to characterize overall water quality in a large area. However, many programs and agencies are already collecting water samples for various reasons. Therefore, a combined strategy needs to be developed to coordinate, at least within the Department, these various groundwater sampling efforts. This coordination may include programs paying for the analysis of "new" parameters in another programs' wells, or merely developing a more efficient means of storing and exchanging ground-water quality data. With the exception of the lower New Castle County monitoring network, all of the data used in this assessment were collected for other purposes. There is much useful data just within the Department, let alone other agencies that could help greatly with overall analysis.

2. Due to the large gap in reliable data for irrigation systems, a recommended step is to locate all operating irrigation wells and surface intakes via GPS, and compile updated

information on the facilities including verification of identification numbers, and other essential attributes.

3. The location of all facilities with water allocations should be updated and a coverage created in the Department GIS.

4. Analyze up-gradient well data from monitored sites to see if there are any regional trends in ground water quality.

5. Determine more accurate base flow loading for impacted streams; compare ground water and surface water data for interactions.

6. Delineation of all source-water protection areas, such as wellhead areas and excellent recharge potential area.

7. Establish wellhead protection ordinances, best management practices, and/or regulations.

8. Identify intensive ground water extractive use in areas that may have water availability issues.

9 Accurately define all sub-cropping aquifer areas to help protect the deeper portions of these aquifers.

10. Develop depth to ground water maps for the entire state that highlight areas with an extremely shallow water table.

11. Review irrigation well water quality for nutrient loading. Incorporate in Management Plans.

12. Refine regional ground-water flow data with information from all possible sites.

13. Determine ground-water system lag time in various sites throughout the state. This could be very helpful in establishing timetables to see results of Pollution Control Strategies.

14. Future recommendations may emerge on permitting irrigation systems on a priority basis for stressed watersheds in order to properly allocate and manage water resources.

2.5.5 REFERENCES

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2.6 WETLANDS

2.6.1 INTRODUCTION

Wetlands represent areas where water is the dominant factor that structures the environment and associated plant and animal communities. These communities are transitional habitats that occur between upland and deepwater habitats, and are considered to be among the most productive ecosystems on earth. They are characterized by fluctuating water tables, wet soils and plants adapted to living in wet conditions.

In recent years, the Delaware Bay and Estuary Basin has lost significant wetland acreage due to development and/or agricultural land conversion. Although the rate of wetland destruction has slowed in recent years, 54 percent of the wetlands in Delaware, of which the Basin is part, have nonetheless been lost since 1780 (Dahl, 1990). Population increase is expected to contribute to further wetland degradation in the foreseeable future. Therefore, implementation of timely preservation efforts is crucial to stem further losses of these ecologically important wetlands.

The ability of wetlands to retain harmful nutrients or to transform them to environmentally harmless forms is well known. In fact, this knowledge has spurred efforts in the scientific and regulatory community to preserve wetlands for the purpose of controlling non-point source pollution. Ignoring or trivializing wetland preservation efforts risks the peril of reducing drinking water quality, fisheries habitat, and various recreational opportunities.

2.6.1.1 Definition

As defined under Section 404 of the Clean Water Act, wetlands are:

"Those areas that are inundated or saturated by surface, or ground water at a frequency and duration sufficient to support, and that under normal circumstance do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, bogs, and marshes, and similar areas."

2.6.1.2 Wetland attributes

The development of attributes unique to wetlands occurs through the interrelationship of hydrology, soils and vegetation. Specific diagnostic characteristics for these three parameters must be exhibited in order to designate an area as a wetland.

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WETLANDS

CONTENTS (Continued)

2.6.1.3 Wetland Hydrology

The presence of water is the most important determinant in the structure and function of a wetland. Water related mechanisms such as ground-water discharge, surface-water runoff, flooding, and tides provide the driving force for creating and maintaining wetlands. These mechanisms affect the nature of soils, which, in combination with water, determine the types of plants and animals that live in a wetlands environment.

2.6.1.4 Hydric soils

Hydric soils are a key attribute for identifying wetlands. Hydric soils are defined as soils that are saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions in the upper soil zone (National Technical Committee for Hydric Soils, 1991). Under these saturated, anaerobic conditions, leaching of common soil constituents (such as iron and manganese) occurs. Visual observation of these depletions (i.e., grey or yellow stains to soil matrix by reducing conditions) and concentrations (i.e., red or black colors imparted to soil matrix by oxidative conditions), is made possible by water-table fluctuations.

A significant portion of the soils that are found in the Basin are poorly to very poorly drained. Many of these soils are associated with the flood plains of creeks and rivers, or with the coastal marsh. Based on recent efforts by Geographic Information System experts in the Department, hydric soils were estimated to comprise at least 43 percent of the Basin's historical land base. It is not certain what percent of the land base is currently occupied by hydric soils. However, it is suspected that the percent would closely mirror the wetland acreage estimates derived from the completed Statewide Wetland Mapping Project (SWMP; see Section 2.6.3.2).

2.6.1.5 Wetland Vegetation

Hydrophytic or wetland vegetation is characterized by dense growths of vegetation adapted to existing hydrologic and soil conditions typical of wetland environments. Wetland plants are adapted to growing under the anaerobic or low oxygen conditions that exist when soils are seasonally saturated to continuously flooded. Wetland plants have adapted to such conditions by developing a variety of structural or physiological adaptations (e.g., stomata size; greater pore space in cortical tissues) that essentially mitigate the normally detrimental effects of reduced oxygen conditions.

2.6.2 WETLAND FUNCTIONS AND VALUES

For many years, wetlands were viewed as disease ridden, worthless wastelands requiring filling, dredging, or channelization. This view has changed significantly in recent years, as the connection between wetlands wildlife, water quality, and other ecological and economic factors have been studied.

Research over the past couple of decades has found that wetlands provide many benefits to society. In fact, some of these values are vital to man's existence. Wetlands intercept pollutants and nutrients from upland runoff, and protect organisms dependent on clean water (humans included) from the poisonous effects of both non-point and point source pollution.

Ecological processes inherent in wetland ecosystems are usually described by functions. An example of a function would be wildlife habitat support. Further classification of a function, on the basis of its value, connotes usefulness to humans. The location of the wetland, human pressures on it, or the extent of the wetland may indicate the value of a functional ecological process (Mitch and Gosselink, 1986). For example, clean water associated with wetlands provides drinking water to upland species, provides an uncontaminated environment necessary for many fish species, and ultimately, recreational value, in the form of hunting and fishing for humans.

It is important to keep in mind the differences between functions and values. Functions are things that a wetland does, and are independent of any attempt to assign an arbitrary monetary value to them. In contrast, values are primarily human constructs, subject to whims of the marketplace. As a result, a wetland with a given function in one locality may be more highly valued than a wetland of similar function in another locality.

Because wetlands are diverse and occupy a variety of habitats, they do not all provide the same functions and values. Therefore, it is generally difficult to determine a wetland's function without a specific site analysis. Variables to consider in assessing a wetland's function includes: wetland type, soils, hydrology, size, and adjacent land use.

Current development practices ignore the importance of preserving wetlands with specific functions crucial to maintaining the environmental integrity of a region or watershed. In other words, development has been allowed in areas (i.e., wetlands) normally deemed unsuitable for conventionally designed septic disposal systems simply because recent technology has enabled the use of alternative septic disposal systems that overcome the limitations imposed by site hydrology. Such development has been carried out without any attempt to assign any ecological or monetary value to the lost wetland functions.

According to Wohlgemuth (1991), wetlands offer three broad categories of values: fish and wildlife habitat values, environmental quality values, and socioeconomic values.

2.6.2.1 Fish and Wildlife Habitat

Wetlands provide food and habitat for a variety of fish, birds, mammals, amphibians, reptiles, and invertebrates. Some of these animals are either fully or partially dependent on wetlands to complete their respective lifecycles. Most commercially important fish species, for example, are wholly dependent on wetlands for spawning and nursery areas. Wetlands also provide breeding ground and habitats for a variety of waterfowl species and fur-bearers. Some species of frogs, toads, and salamanders depend on wet habitat for their survival, and provide food for animals in higher trophic levels. Reptiles, such as turtles and snakes, use these areas for the same reasons as the above. Invertebrates, such as aquatic bugs or insects, are important in the maintenance of the food web.

Additional information on the interdependence of wetlands with fish and wildlife habitat can be found in the living resources section (refer to Section 2.7).

2.6.2.2 Environmental Quality Benefits

Wetlands are considered among the most productive ecosystems in the world. Wetland plants produce more plant material than most very productive cultivated farm fields. The major value of wetland plants occurs when the plants die and are broken down into detritus by bacteria and other microrganisms. Detritus forms the base of the food web that supports higher animals such as commercial fish species. Wetlands also help maintain and improve water quality.

The following are specific environmental quality benefits of wetlands:

- Pollutant removal (heavy metals, pathogens);
- Sediment trapping;
- Nutrient uptake and recycling;
- Oxygen production;
- Wastewater treatment; and
- Stormwater treatment

2.6.2.3 Socioeconomic Values

Some of the benefits that wetlands provide are of more tangible economic value, such as protection from flood and storm damage. Because these benefits provide dollar savings, they tend to be more appreciated.

The following are some socioeconomic wetland values:

- Flood and stormwater damage protection;
- Erosion control;
- Water supply and ground-water recharge;
- Natural products supply (e.g., timber, fish, wildlife, firewood, etc.); and
- Recreation (e.g., waterfowl, fishing, boating, nature study, etc.)

2.6.3 NATIONAL WETLANDS INVENTORY AND THE STATEWIDE WETLAND MAPPING PROJECT

2.6.3.1 Introduction

In response to the need to inventory and classify wetlands, the U.S. Fish and Wildlife Service, under the supervision of Cowardin and others (1979), developed a method to consistently classify various wetland types throughout the U.S. The resultant "Classification of Wetlands and Deepwater Habitats of the United States" was a comprehensive classification of all aquatic and semi-aquatic ecosystems. The "Cowardin Classification System", as it is frequently referred, was first employed in the U.S. Fish and Wildlife Service's National Wetlands Inventory (NWI) maps.

2.6.3.2 Statewide Wetlands Mapping Project

The Cowardin classification scheme has subsequently been adapted for use in the Statewide Wetland Mapping Project. The SWMP is a collaborative project between DELDOT and the

Department, and involves an interdisciplinary group of wetland scientists, mapping experts, and engineers. The goal of the SWMP is to improve and update existing wetland inventories and transportation resources. Maps generated from this project are hardcopy and digital SWMP maps (*see Map 2.6-1 Wetland Types and Locations*). These maps or orthophotographs exhibit various wetland signatures in the form of hues, or darkness/lightness variations, characteristic of specific vegetative types or hydrologic regimes. These photointerpreted signatures, in conjunction with existing wetland inventories, soil survey information, QA/QC field verification data, and other ancillary data, are used to delineate wetland boundaries or polygons on the SWMP orthophotos (Pomatto, 1994). The photointerpreted maps, like the NWI maps, utilize alphanumeric codes to convey information about specific wetlands.

The use of aerial color-infrared digital orthophotography by the SWMP is a significant improvement over the less distinctive monochromatic NWI maps. The fact that a skilled photointerpreter can delineate and identify mapping units such as vegetative types (e.g., broad-leaved deciduous, broad-leaved evergreen, etc.), or hydrologic regimes (e.g., A, B, C, etc.) with greater precision and accuracy is one of the chief advantages of aerial color photography.

2.6.3.3 Cowardin Classification Scheme applied to NWI or SWMP

This classification scheme is based on a hierarchial approach to classifying wetland types that is analogous to classification of animal or plant species. In this scheme, wetlands are broadly classified into five systems: Marine, Estuarine, Riverine, Lacustrine, and Palustrine. Marine and Estuarine systems are found along coastal environments on the eastern side the Delaware Bay Basin. There are three categories of freshwater wetland systems. Riverine systems are associated with rivers and streams, and are restricted to aquatic beds within channels, and to fringes of nonpersistent emergent plants growing on riverbanks or in shallow water. Lacustrine systems are associated with freshwater lakes or deepwater habitats greater than 2 meters deep at low water, and greater than 20 acres in size. Palustrine systems areas are also freshwater systems, but are differentiated from lacustrine systems on the basis of water depth and size. Wetland systems such as Palustrine, which means marshy, are wetland systems that describe specific wetland categories such as marshes, swamps, and bogs. Palustrine wetlands and waterbodies are wetlands and water bodies that are less than 2 meters deep at low water, and smaller than 20 acres in size. They may be either non-tidal or tidal wetland systems.

As mentioned above, the Cowardin Classification system uses an hierarchial approach to classifying and delineating wetland types. This system consists of an ordered series or numbers and letters (alphanumeric coding) that reflect specific characteristics of wetlands and deepwater habitats. This classification system begins with the most broadly defined concepts (e.g., Systems), and ends with very specific descriptive modifiers (*see Table 2.6-1 and Figure 2.6-1*).

The system is represented by the first letter in the alphanumeric code, and this letter is capitalized. Each system (except the Palustrine System) is divided into sub-systems based on major hydrologic, geomorphologic, chemical, and biological characteristics. Sub-systems are denoted as numeric characters following the system symbol. Sub-systems are divided into classes, which describe the general vegetative appearance in terms of vegetative lifeform, or the composition of the substrate (e.g., Forested, Scrub-shrub, etc.). Classes are denoted by upper-case letters (e.g., "Scrub-shrub" is "SS"). Classes are subdivided into subclasses, which describe specific vegetative or substrate types (e.g., Broad-Leaved Deciduous, Needle-Leaved Deciduous, or Bedrock, Rubble, etc.), and are designated by numeric modifiers specifically keyed to the vegetative or substrate type. Following the subclass is an upper case letter denoting the hydrologic regime. Hydrologic regimes (e.g., temporarily flooded, seasonally saturated, etc.) are coded to specific hydrologic types on the basis of frequency and duration of flooding. Additional refinement of the classification scheme is provided by modifiers, which describe specific hydrologic, chemical, soil, human impact and/or other characteristic of a particular wetland (*see Table 2.6-1 and Figure 2.6-1*)

2.6.4 WETLAND VEGETATION AND PLANT COMMUNITIES

2.6.4.1 Introduction

Wetland plant community structure and composition are influenced by many factors, including: climate, hydrology, water chemistry and human activities. Important physical factors include: 1) location of the water table; 2) fluctuation of the water table; 3) soil type; 4) soil acidity; and 5) salinity. Biotic factors (i.e., plant competition, animal actions, and human activities) also play a role in structuring a community. Plant composition if often altered by channelization and drainage of wetlands. Generation of surface spoil piles and altered surface-water drainage patterns often gives some undesirable plant species (e.g., phragmites) a competitive advantage.

2.6.4.2 Definition of a Hydrophyte

Hydrophyte is the technical term applied to plants adapted to wetland environments. The U.S. Fish and Wildlife Service defines a hydrophyte as "any plant growing in water or on a substrate that is at least periodically deficient in oxygen as a result of excessive water content" (Cowardin and others, 1979).

Table 2.6-1 Adapted and revised NWI modifiers for Delaware's SWMP

WATER REGIME		WATER CHEMISTRY			SOIL	SPECIAL	DELAWARE
Non-Tidal	Tidal	Coastal Halinity	Inland Salinity	pH Modifiers for Fresh Water			
A Temporarily Flooded	K Artificially Flooded	1 Hyperhaline	7 Hypersaline	a Acid	g Organic	b Beaver	1 Endangered Species/ Community
B Saturated	L Subtidal	2 Euhaline	8 Euhaline	t Circumneutral	n Mineral	d Partially Drained/ Ditched	2 Coastal Plain Pond
C Seasonally Flooded	M Irregularly Exposed	3 Mixohaline	9 Mixohaline	l Alkaline		f Farmed	3 Atlantic White Cedar Community
D Seasonally Flooded/Well Drained	N Regularly Flooded	4 Polyhaline	0 Fresh			h Diked/ Impounded	4 Bald Cypress Community
E Seasonally Flooded/ Saturated	P Irregularly Flooded	5 Mesohaline				r Artificial Substrate	5 Interdunal
F Semipermanently Flooded	S Temporary-Tidal	6 Oligohaline				s Spoiled	6 Acidic Sea-Level Fen
G Intermittently Exposed	R Seasonal-Tidal	7 Fresh				x Excavated	7 Riparian
H Permanently Flooded	T Semipermanent-Tidal						8 Category I Buffer Wetland
J Intermittently Flooded	V Permanent-Tidal						9 Seasonally Flooded or Wetter Pf
K Artificially Flooded	U Unknown						10 Pf Drier than Pf 9
Intermittently Flooded/ Temporary							11 State-Regulated Wetlands
Y Saturated/ Semipermanent/ Seasonal							
Z Intermittently Exposed/ Permanent							
U Unknown							

2.6.4.3 Plant Indicator Status Categories

The U.S. Fish and Wildlife Service recognizes four types of hydrophytes:

Obligate - Obligate hydrophytes are plants that almost always (estimated probability greater than 99 percent) occur in wetlands, but may occur (estimated probability less than 1 percent) in non-wetlands.

Facultative wet - Facultative wet plants (estimated probability greater than 67 percent to 99 percent) in wetlands, but also occur (estimated probability of 1 percent to 33 percent) in non-wetlands.

Facultative - Facultative plants (estimated probability 33 percent to 66 percent) are as likely to grow in both wetlands or in non-wetlands.

Facultative upland - Facultative upland plants are sometimes (estimated probability of 1 percent to 33 percent) found in wetlands, but occur (estimated probability (greater than 67 percent to 99 percent) in non-wetlands.

Vegetation is considered hydrophytic when 50 percent of all vegetative strata (e.g., tree, shrub, vine and herb) have an indicator status of facultative or wetter (Tiner, 1985).

2.6.5 UNIQUE OR THREATENED WETLANDS

The Delaware Bay and Estuary Basin contains a number of unique and threatened wetland types. These unique or threatened wetland community types in the Basin include:

- Bald Cypress (Taxodium distichum);
- Atlantic White Cedar (Chamaecyparis thyoides);
- Coastal plain ponds (i.e., Carolina bays/Delmarva bays);
- Acidic Sea-level fens; and
- Interdunal swales.

These communities are considered priorities for protection due to rare species that they often contain, their growth form, and/or their unusual geomorphic setting or geologic origin (McAvoy and Clancy, 1993). In recognition of this fact, the Department and the Delaware Natural Heritage Program identified, inventoried, and mapped these unique wetlands for purposes of regulatory protection and resource management. Those wetlands deemed most threatened or unique were classified as Category I wetlands, while wetlands considered less threatened or unique were assigned higher category numeric designations (i.e., Category II and III). For semantic reasons, the term "categories" has subsequently been changed to "types". However, the numeric designations representing specific wetland types remain the same. Additional information on unique or threatened wetlands can be found in the living resources section of this document.

2.6.6 DISTRIBUTION OF WETLAND TYPES

2.6.6.1 Introduction

The presence of dense growths of plants adapted to the existing hydrologic, chemical, and soil conditions is the most conspicuous characteristic of wetlands in the Delaware Bay and Estuary Basin, especially large expanses of tidal marsh. As mentioned previously, five major wetland systems are recognized: Marine, Estuarine, Riverine, Palustrine, and Lacustrine, and they comprise 100 percent of the total wetland acreage, and approximately 29 percent of the Basin's total land area.

2.6.6.2 Palustrine Wetlands

Palustrine wetlands (i.e., bottomland forests, swamps, and marshes) comprise the vast majority (greater than 93 percent) of the inland/non-coastal freshwater wetlands found within Delaware's portion of the Basin. These wetlands have the greatest floral diversity of any wetland system due to their exposure to the greatest range of moisture regimes (Tiner, 1985). Palustrine wetlands may be tidaly-influenced, and may include riparian and headwater riparian areas.

Riparian Wetlands

Riparian wetland is a sub-category of Palustrine wetlands. These wetlands are immediately adjacent to streams, rivers, or other waterbodies, but are most often associated with low order streams. Riparian wetlands comprise approximately 25 percent of the total wetland base in the Basin. These wetlands are very important for enhancing both ecological and water quality values because they maintain unbroken wildlife corridors to the flooplain area, and reduce sediment and nutrient loading downstream. Brinson (1993) recognized ecological and water quality values provided by low-order streams. He found that riparian transport (non-channelized overland flow, or groundwater quickflow following storms from upland to downstream) is more effective for nutrient and sediment removal than overbank flow from high-order flooplain systems. Brinson also noted that, as floodplain width narrows moving upstream (i.e., decreasing stream order), there is an exponential increase in the length of floodplain affected. In other words, low-order riparian wetlands are affected proportionally more per unit length area by anthropogenic impacts than wetlands associated with higher-order streams. Most of the coastal plain streams in the Basin are dominated by riparian flow.

Headwater Riparian Wetlands and Marginally-Wet Riparian Wetlands_

Because of their initial connection to the floodplain system (first-order streams), headwater riparian wetlands are considered extremely important. According to the Conservation Design for Stormwater Management manual (1997), Delaware (including the Basin) has predominately first-order through third-order streams. The smallest first-order riparian areas, only three meters wide, make up roughly one-third of the total floodplain area for most of the watersheds in the State.

Brinson (1993) found that low-order streams, because of their large surface area, are more susceptible to adverse environmental impacts than higher-ordered floodplain environments. Therefore, protecting these smaller headwater riparian areas can aid in safeguarding the ecological integrity of the larger downstream floodplain systems.

The environmental integrity of headwater riparian wetlands is also often dependent on the surrounding upland environment. Upland forests provide additional water quality benefits by trapping sediments and converting nutrients to biomass prior to discharge into riparian wetlands (i.e., reducing sediment and nutrient load into the adjacent riparian wetlands).

Figure 2.6-1 Modified Cowardin Classification System for Delaware Wetlands

PALUSTRINE

SYSTEM

CLASS	RB-Rock	UB-Unconsolidated Bottom	AB-Aquatic Bed	US-Unconsolidated Shore	EM-Emergent	SS-Scrub-Shrub	FO-Forested	OW-Open Water
Subclass	1. Bedrock	1. Cobble-Gravel	1. Algal	1. Cobble-Gravel	1. Persistent	1. Broad-Leaved Deciduous		
	2. Rubble	2. Sand	2. Aquatic Moss	2. Sand	2. Nonpersistent	2. Needle-Leaved Deciduous		
		3. Mud	3. Rooted Vascular	3. Mud		3. Broad-Leaved Evergreen		
		4. Organic	4. Floating Vascular	4. Organic		4. Needle-Leaved Evergreen		
			5. Unknown Submergent	5. Vegetated				
			6. Unknown Surface					

RIVERINE

SYSTEM

SUBSYSTEM 1-Tidal 2-Lower Perennial 3. Upper Perennial 4-Intermittent 5-Unknown Perennial

CLASS	RB-Rock	UB-Unconsolidated Bottom	SB-Streambed	AB-Aquatic Bed	RS-Rocky Shore	US-Unconsolidated Shore	EM-Emergent	OW-Open Water
Subclass	1. Bedrock	1. Cobble-Gravel	1. Bedrock	1. Algal	1. Bedrock	1. Cobble-Gravel	1. Persistent	
	2. Rubble	2. Sand	2. Rubble	2. Aquatic Moss	2. Rubble	2. Sand	2. Nonpersistent	
		3. Mud	3. Cobble-Gravel	3. Rooted Vascular		3. Mud		
		4. Organic	4. Sand	4. Floating Vascular	4. Organic			
			5. Mud	5. Unknown Submergent		5. Vegetated		
			6. Organic	6. Unknown Surface				
			7. Vegetated					

ESTUARINE

SYSTEM

SUBSYSTEM SUBTIDAL

CLASS	RB-Rock Bottom	UB-Unconsolidated Bottom	AB-Aquatic Bed	RF-Reef	OW-Open Water Unknown Bottom
Subclass	1. Bedrock	1. Cobble-Gravel	1. Algal	1. Coral	
	2. Rubble	2. Sand	2. Aquatic Moss	2. Mollusc	
	3. Mud	3. Rooted Vascular		3. Worm	
	4. Organic	4. Floating Vascular			
		5. Unknown Submergent			
		6. Unknown Surface			

INTERTIDAL

AB-Aquatic Bed	RF-Reef	SB-Streambed	RS-Rocky Shore	US-Unconsolidated Shore	EM-Emergent	SS-Scrub-Shrub	FO-Forested
1. Algal	1. Coral	1. Cobble-Gravel	1. Bedrock	1. Cobble-Gravel	1.Persistent	1. Broad-Leaved Deciduous	
2. Aquatic Moss	2. Molluse	2. Sand	2. Rubble	2. Sand	2. Nonpersistent	2. Needle-Leaved Deciduous	
3. Rooted Vascular	3. Worm	3. Mud		3. Organic		3. Broad-Leaved Evergreen	
4. Floating Vascular		4. Organic				4. Needle-Leaved Evergreen	
5. Unknown Submergent							
6. Unknown Surface							

Protection of headwater riparian wetlands is of critical importance for maintaining the ecological integrity of the entire floodplain system. A lack of regulatory protection and recognition of their ecological importance has often allowed marginally wet headwater wetlands to be filled and/or developed. It is imperative to enact regulations/and or conservation practices to protect these lands. Conservation practices (e.g., riparian buffers, conservation easements both for farmlands and upland forests, etc.), either through regulatory or economic incentives, would significantly help to maintain a high quality environment.

2.6.6.3 Estuarine Wetlands

Estuarine wetlands are systems associated with coastal salt or brackish waters. These areas extend upstream into coastal rivers to the point where salinity levels decline to negligible measurable levels (less than 0.5 parts per thousand (ppt)). These wetland systems comprise the majority (greater than 99 percent) of our coastal wetland resource and 59 percent of the wetland base within the Basin.

Estuarine wetlands are the foundation for total estuarine productivity, and although quite plain and monotype in appearance, are a product of many dynamic biological, chemical, physical and geological processes. These estuarine ecosystems are dominated by only a handful of plants (typically *Spartina alterniflora*) and distinct sets of animal species. These species, both plant and animal, have adapted to what is not normally viewed as an extremely stressful ecosystem.

2.6.6.4 Lacustrine Wetlands

Lacustrine wetlands are systems such as deepwater habitats associated with lakes, reservoirs, and deep ponds. These wetland systems comprise approximately two percent of the wetland base within the Basin.

2.6.6.5 Riverine Wetlands

Riverine wetlands are systems that encompass freshwater rivers and their tributaries, including the freshwater tidal reaches of coastal rivers where salinity is less than 0.5 ppt. These wetland systems comprise less than one percent of the wetland base within the Basin.

2.6.7 WETLAND LOSSES AND TRENDS

2.6.7.1 Introduction

The Delaware Bay and Estuary Basin is approximately 814 square miles. The Basin has lost a significant amount of wetlands acreage, although the rate of loss has slowed with increased introduction of wetland regulations. The following trend studies outline wetland losses and trends since the 1950s.

2.6.7.2 Wetland Trend Study by Tiner (1994)

According to this study, wetlands occupied approximately 150,000 acres in the Delaware Bay Basin in 1992. This study also showed that, during the study period (1981/2 - 1992), palustrine vegetated wetlands decreased by a net total of 747 acres, and estuarine wetlands by 80 acres.

Of the four most common wetland types found within the Basin (Estuarine emergent (E2EM), Palustrine forested (PFO); Palustrine scrub-shrub (PSS), and Palustrine emergent (PEM)), PFO wetlands suffered the greatest losses of 444 acres. Additionally, there were 198 acres of PSS, 80 acres of E2EM, and 36 acres of PEM lost during the trend study period.

The Delaware Bay and Estuary Basin also contains about 39 tax ditch organizations. The extensive network of ditches impairs, to some extent, the natural functions of wetlands. As a result, large acreages of wetlands have been lost or irrevocably impacted by channelization activities.

2.6.7.3 Wetland Trend Study by Dahl et al. (1997)

Wetland loss concerns prompted an additional study by the United States Fish and Wildlife Service (USFWS). The study entitled "Status and Trend of Wetlands in the Conterminous United States" by Dahl and others (1997), for the USFWS, is the most recent attempt by this agency to determine wetlands losses and trends. The study projected wetland losses by using a statistical sampling design, random sample plots combined with special mathematical techniques, and updated photointerpretation.

Although this technique projected wetland losses over wide geographic regions beyond the Delaware Bay and Estuary Basin, it provided a reasonable estimate of the wetland losses in our region. The projected wetland loss for the northeastern physiographic stratum, which encompasses the Delaware Bay and Estuary Basin, was estimated to be 20 percent between 1985 and 1995 (Dahl and others 1997). Most of the loss of wetlands estimated during this time period was due to conversion of wetlands for agricultural land use.

Wetland losses between the mid-1950s and the late 1970s were considerably greater than wetland losses that occurred between 1985 and 1995. According to Tiner (1987), approximately 21 percent of Delaware's inland vegetated wetlands and six percent of its coastal wetlands disappeared during the earlier time period. However, like the wetland loss figures presented from Dahl's report, these wetland-loss figures are for a somewhat larger geographic area (in this case, the entire State of Delaware). Nevertheless, these figures provide a reasonable estimation of wetland losses experienced in Delaware's portion of the Delaware Bay and Estuary Basin.

2.6.8 REGULATIONS FOR PROTECTION OF AQUATIC AND WETLAND RESOURCES

There are several Federal and State level laws designed to protect the water resources and wetlands of Delaware. The most significant statutes at the federal level include the Rivers and Harbors Act of 1899, and the Clean Water Act of 1972. The most significant State laws are the Wetlands Act of 1973, and Subaqueous Lands Act of 1969. The United States Army Corps of Engineers administers the federal laws. The Wetlands and Subaqueous Lands Section of the Department's Division of Water Resources administers the state laws. Although there are some jurisdictional differences between the federal and state programs, the Corps of Engineers and the Wetlands and Subaqueous Lands Section coordinate their programs to minimize overlapping authority. Additionally, the Wetlands and Subaqueous Lands Section has assumed authority for certain jurisdictional functions formally handled by the Corps of Engineers. Both agencies have developed expedited procedures for reviewing projects under their jurisdiction.

2.6.8.1 Rivers and Harbors Act of 1899

The Rivers and Harbors Act of 1899 regulates activities in navigable waters of the United States. Navigable waters are defined in Delaware as all tidal waters and their tributaries to the head of the tide. In tidal waters, the shore boundary extends to the mean high water line. In non-tidal waters, the shore boundary extends to the ordinary high water line.

The law applies to any dredging or disposal of dredged materials, excavation, filling, rechannelization, or other modifications of a navigable waterway. The law also applies to construction of structures, including but not limited to, docks, piers, jetties, groins, weirs, breakwaters, shoreline protection (e.g., rip-rap revetments or bulkheads), pilings, aerial or subaqueous utility crossings, intake or outfall pipes, boat ramps or navigational aids.

2.6.8.2 The Clean Water Act

Section 404 of the Clean Water Act requires authorization from the Army Corps of Engineers for the discharge of dredged or fill material to go into waters of the United States, including wetlands. This Act applies to navigable waters, their tributaries, intermittent streams, lakes, ponds and wetlands. The criteria for determining whether an area is a wetland subject to Corps jurisdiction is contained in the "Corps of Engineers Wetlands Delineation Manual." The criteria are based on specific vegetation, soil and hydrology characteristics (Environmental Laboratory, 1987).

Permits are also required for temporary-impacting projects such as temporary fills for access roads, cofferdams, storage and work areas, or dewatering of dredged material prior to final disposal.

2.6.8.3 Federal Permitting Requirements

Permits issued by the Corps of Engineers pursuant to the requirements of the Rivers and Harbors Act and the Clean Water Act are designed to ensure that this nation's water resources are safeguarded and used in the best interest of the people. Environmental, social, and economic concerns are weighed as part of the permit application process. The Corps makes their decision about whether to issue a permit after a thorough analysis of a proposed activity's probable impacts, including its cumulative impact on the public. Numerous factors, including general environmental concerns and existence of wetlands, are taken into consideration. Permits are generally issued unless the Corps of Engineers determines the proposed activity is not in the public interest.

To expedite the permitting process, the Corps of Engineers developed a system of nationwide and general permits designed to reduce the paperwork and time necessary to obtain an individual permit. Nationwide permits allow numerous pre-authorized activities. Activities include bank stabilization, road and utility crossings in wetlands, minor filling of wetlands, filling of headwaters, construction of boat ramps, and placement of mooring buoys. All such activities are conducted under certain pre-authorized conditions mandated by the Corps of Engineers. In Delaware, some of these nationwide permits have been denied under sub-section 401, water quality certification.

General permits are designed to expedite the permitting process for certain structures in navigable waters. These permits are also designed to meet criteria specific to the state in which they are issued. General permits are issued by the Wetlands and Subaqueous Lands Section by agreement with the Corps of Engineers.

2.6.8.4 The Wetlands Act

Tidal wetlands in Delaware are protected under the Tidal Wetlands Act of 1973 (7 Del.Code, Chapter 66). The act and the regulations written pursuant to the law regulate activities in tidal wetlands. Tidal wetlands are defined as:

"Those lands above the mean low water elevation including any bank, marsh, swamp, meadow, flat or other low land subject to tidal action in the State along the Delaware Bay and Delaware River, Indian River Bay, Rehoboth Bay, Little and Big Assawoman Bays, the coastal inland waterways, or along any inlet, estuary or tributary waterway or any portion thereof, including those areas which are now or in this century have been connected to tidal waters, whose surface is at or below an elevation of 2 feet above local mean high water, and upon which may grow or is capable of growing any but not necessarily all of the following plants: [list of plants] and those lands not currently used for agricultural purposes containing 400 acres or more of contiguous nontidal swamp, bog, muck or marsh exclusive of narrow stream valleys where fresh water stands most, if not all, of the time due to high water table, which contribute significantly to groundwater recharge, and which would require intensive artificial drainage using equipment such as pumping stations, drainfields or ditches for the production of agricultural crops."

Tidal wetlands meeting this definition have been delineated on maps available from the Department. These maps are for public use to determine whether an area is a tidal wetland. The law states that a permit is required for any activity conducted in a tidal wetland. Activities include dredging, draining, filling or bulkheading. They also include construction of any kind, including but not limited to, construction of a pier, jetty, breakwater, boat ramp, or mining, drilling, or excavation. Projects that are exempted from the permit requirement include mosquito control activities authorized by the Department, construction of directional aids to navigation, duck blinds, foot bridges, boundary stakes, wildlife nesting structures, grazing or domestic animals, haying, hunting, fishing and trapping.

The Department's Wetlands and Subaqueous Lands Section issue permits. Applications for a permit are evaluated for environmental impact, aesthetic effect, the number and type of supporting facilities, including their environmental impact, and their effect on neighboring land uses. State, county and municipal comprehensive plans for the development and/or conservation of their areas of jurisdiction and economic effect also are considered. All applications are put on public-notice and any comments received are resolved prior to issuance of a permit.

Although not explicitly cited in the law or regulations, mitigation, in the form of creating compensatory wetlands, is required to offset the impacts of displacing wetlands for some public works projects, including those conducted by the State Department of Transportation.

The Wetlands Act has proven very effective in controlling destruction of tidal wetlands. During 1995 through 1996, less than one acre of tidal wetlands was permanently displaced under the permitting process.

Non-tidal wetlands comprise the vast majority of wetlands in the State, including the Delaware Bay and Estuary Basin. Currently, the State of Delaware does not have a regulatory mechanism for protecting non-tidal wetlands, although there are efforts underway that could change this.

The SWANCC Decision

On January 9, 2001, the Supreme Court of the United States handed down a decision in the case of Solid Waste Agency of Northern Cook County (SWANCC, Illinois) vs. The United States Army Corps of Engineers (Corps) in favor of SWANCC. The result of the ruling removed the Corps' regulatory jurisdiction over isolated freshwater wetlands under Section 404 of the Clean Water Act. Generally, the ruling stated that the presence of migratory birds alone could not be considered "interstate commerce," which is the term that captures isolated wetlands along with other wetlands regulated under Section 404 of the Clean Water Act. The effect of this ruling on freshwater wetlands is now being assessed across the United States, including Delaware. Delaware contains approximately 30,000 acres of isolated freshwater wetlands that now have no regulatory protection. Many of these acres are headwater, forested wetlands (discussed previously for their water-quality importance), but also include ecologically unique wetland types such as Delmarva Bays. Currently, various options at the state level for protecting these valuable, isolated freshwater wetlands include developing new legislation; changing the extent of 401 Water Quality Certification; or, modifying the Wetlands Act to include these areas.

2.6.8.5 The Subaqueous Lands Act

Rivers, streams, and other bodies of open water are protected under the State Subaqueous Lands Act (7 Del. Code, Chapter 72). The stated purpose of the Subaqueous Lands Act and the regulations written pursuant to the law is to protect subaqueous lands against uses or changes which may impair the public interest in the use of tidal or navigable waters. Subaqueous lands are defined as "submerged lands and tidelands."

Subaqueous lands subject to jurisdiction under the law are shown on U.S. Geological Survey 7.5-Minute Series (Topographic) Quadrangle Charts for the State of Delaware. The law states that a permit is required for certain activities conducted in subaqueous lands. Activities include dredging, draining or filling, and construction of any kind.

Permits are issued by the Wetlands and Subaqueous Lands Section. The Regulations Governing the Use of Subaqueous Lands stipulate that no activity may be undertaken which might contribute to the pollution of public waters, adversely impact or destroy aquatic habitats, or infringe upon the rights of public or private owners. The regulations specify the requirements for constructing boat docking facilities, shoreline erosion control measures, and activities involving dredging, filling, excavating, or extracting materials in public and privately owned subaqueous lands. Applications for permits are put on public notice to solicit public input. The application process is also coordinated with the Army Corps of Engineers.

To expedite the permitting process, a system of statewide activity approvals has been developed by the Wetlands and Subaqueous Lands Section. The statewide activity approvals provide an abbreviated review process and authorization for relatively small projects. Applicable projects range from docks or rip-rap revetments in artificial lagoons to placement of utility lines across streams. Repair and replacement of existing structures is handled by an abbreviated review process and follow-up Letter of Authorization.

2.6.9 WETLANDS MITIGATION AND COMPENSATION

2.6.9.1 Introduction

Any significant construction project may negatively impact tidal and/or non-tidal wetlands. Today, such projects (and their impacts) usually require some level of permit approval that ensures compensation for wetland impacts. Generally, wetlands in non-tidal areas are regulated by the federal government (U.S. Army Corps of Engineers), while tidal areas are regulated by the Department. In some instances, wetlands compensation is required by one or both of these agencies as any project may impact jurisdictional wetlands in both tidal and non-tidal areas. Depending on the quality of the negatively impacted wetland, the requirements for replacement/compensation vary in both size and quality. Where compensation requirements overlap, the federal agency requirements usually take precedent.

Among wetlands resource managers, scientists, and the general public, wetlands "compensation" and wetlands "mitigation" are used synonymously to describe wetlands compensation. To clarify, wetland mitigation is the actual process by which a person conducting a project must complete to reach the stage of compensation. The mitigation process involves investigating project alternatives for avoiding impacts, rectifying actual impact by repairing, reducing/minimizing impact, and compensating for unavoidable impacts. Traditionally, compensation has taken place at or near the site of impact (i.e., on-site) and involves replacement of the impacted wetlands with wetlands of similar type (i.e., in-kind). In some unavoidable circumstances, compensation must take place away from the site of impact.

2.6.9.2 Wetland Compensation Goals

The original intent of wetlands compensation was to attempt to replace the impacted wetlands with one adjacent to it so that species of plants and animals would not be displaced, and wetland functions would not be completely lost. While in many cases this intent remains a viable option, wetland scientists and resource managers have acknowledged that the on-site and in-kind type of replacement compensation is often not practical. Impracticalities of this option are often shown to out-weigh the benefits. In most cases, the replacement wetland has to be a created wetland, and created wetlands generally have a lower success rate compared to restoring a previously converted wetland, or enhancing a wetland in need of improvement. It is much more difficult to create a wetland where one has not previously existed. The inability to maintain appropriate hydrologic regimes, as well as replacing wetlands occupying specific niches, can be problematic. Developers are also wary of the cost of creating versus restoring a wetland. Consequently, "off-site" and even "out-of-kind" compensation projects are now an alternative that have become part of the mitigation decision making process.

Increased flexibility in the wetlands mitigation process has improved the success rate of compensation projects. In the past, the creation, restoration, and even the enhancement of wetlands had been a very inexact science. Through the evaluation of data derived from increased research and completed compensation projects, it has become apparent that the use of replacement wetlands to offset impacts is both viable and more stable. Continually evolving wetlands assessment methodologies, coupled with the identification of planning issues associated with wetland compensation projects, have contributed to this realization. These planning issues include: type of hydrologic source desired (i.e., groundwater, surface water run-off and/or overbank flow); presence/absence of an open water component; type of vegetation needed to develop the desired community type; and geology/soils investigation to determine whether existing substrates are conducive to wetland development.

In addition, the establishment of a more flexible mitigation and compensation process is what State of Delaware resource managers need to properly plan for to ensure conservation of water and wetland resources. Certain watersheds need improvements whether they are for water quality, habitat, nutrient removal, or any other of the functions that wetlands can provide. Depending on the size of the compensation project, wetlands can be strategically placed to make improvements on either a sub-watershed or watershed level. A very large compensation project, or a wetlands compensation bank, could provide an even greater mechanism to achieve these same goals.

2.6.9.3 Wetland Compensation Banks

The purpose of wetland compensation banks is to establish compensation "credits" for wetlands that have been negatively impacted. For example, wetlands in one area or region can be replaced by a created, restored, or enhanced wetland in another. The permit requirements and mitigation sequencing of the federal agencies would be best served by wetland banks, and the reduction of wetland impacts as part of the mitigation process results in a need for banks. Through the sequencing process the result is usually lower amounts of required compensation. Instead of doing a multitude of small compensation projects, a bank can offer more value when the bank is strategically located in a watershed of need. Although there are projects with large impacts, the majority of projects impacting wetlands only require minor compensation.

The siting of wetland banks can offer a wide range of wetland benefits (e.g., water purification and filtration, flood attenuation, ground-water recharge) and values (e.g., recreation, fish and wildlife habitat, education, aesthetics, uniqueness and heritage) in comparison to smaller piece-meal wetland compensation sites. Another advantage of wetland banks is they can be constructed and functioning (both administratively and ecologically) in advance of project impacts, thereby reducing temporal losses, as well as reducing the risk of failure associated with individual wetland compensation projects. With individual wetland compensation sites, the created or restored wetlands are not fully functioning until well after the impact has occurred. In pre-planning these wetland banks, resource management and regulatory agencies can coordinate more effectively, and, through improved planning, provide more attention to meeting multiple ecological objectives. Permit timing is also reduced if compensation wetlands are available at a bank for a developer to use. In summary, establishment of wetland banks can more efficiently combine financial resources, planning expertise and scientific expertise.

Monitoring of wetland banks may provide information to improve the probability of success for subsequent mitigation efforts. The required monitoring of banks is usually for a five-year period, with a maintenance requirement of much longer duration. This level of monitoring will ensure that the integrity of a wetland bank is maintained.

Wetland banks have already become a landscape feature in some areas of Delaware. For the most part, the Delaware Department of Transportation has created banks to address impacts associated with roadwork. These banks have occurred mostly near the Route 1 corridor. There are many developers and consultants that have an interest in banking and have expressed their desire to develop banks. These "private sector" banks are in the planning stages and will probably be constructed within the next few years.

At this time, there are no wetland banks in the Delaware Bay and Estuary Basin, nor are any planned in the near future (minus the network of DelDOT wetland compensation sites). The increase in development within the Basin will ultimately require a wetland bank to compensate for wetland impacts within the Basin. There have been small compensation projects within the Basin. These smaller wetland compensation projects are almost exclusively associated with drainage/tax ditch projects.

2.6.10 WATER MANAGEMENT

2.6.10.1 Historical Perspective and Need

Many areas of the nation have historically based land uses on an infrastructure of man-made drainage systems. Delaware is no exception, and it has community and private drainage systems that date back to the 1700s. In the 1700s, drainage of wetlands was considered necessary for several reasons (e.g., food was desperately needed for armies and war-ravaged countries, so farming of every available acre was necessary; wetland-related diseases seriously affected populations; timber harvests were essential, etc.). The extensive drainage patterns constructed in early times were extensions of natural drainage patterns into poorly-drained upland flats. These channels were constructed to better manage soil and water resources, and for flood protection.

The average annual rainfall in Delaware usually exceeds plant needs and evaporation rates, creating excess water for extended periods. The result is drainage and flooding problems for agricultural areas, as well as towns, rural communities, forests, and transportation facilities.

Without proper drainage systems, soils become over-saturated, or have standing water on them. This situation precludes efficient farming operations, as farmers cannot get into their fields for timely agricultural operations. Adverse effects on crop production include: 1) inability to prepare soils for planting; 2) delays beyond optimum planting dates; 3) inhibited plant growth due to excess water in the soil profile; and 4) restricted harvests and/or the inability to harvest. In addition, crops impacted by flooding or poor drainage often underutilize nutrients, thereby creating potential excess nutrient contamination problems in downstream areas. Approximately 23 percent of the soils in the Delaware Bay and Estuary Basin are poorly drained due to low permeable clay-type subsoil.

Today, proper water management for optimizing farming operations has become even more vital due to increasingly complex and expensive equipment and inputs (such as fertilizers and chemicals). The existence of stable drainage systems plays a large role in determining the economic success of many farming operations within the Basin. In addition to farming concerns, many rural roads depend on proper drainage outlets to control flooding, and to minimize upkeep and maximize longevity.

For urban communities, controlling surface-water runoff is critical. Proper drainage in areas with residential and industrial development is essential for maximum utilization of related facilities. Basements, septic systems, streets, recreational areas, stormwater facilities, parking lots, schools, and businesses all depend on an effective drainage system for proper utilization. Numerous programs, some dating back to the 1700s, have been implemented to address drainage and flooding issues.

The development of a drainage infrastructure in Sussex County received a large boost in 1935 when the Levy Court was authorized to sell bonds for drainage improvements. Ditch company operations for care and maintenance were also turned over to the Levy Court. Additionally, significant assistance came in the 1930s and 1940s with the formation of the Works Progress Administration (WPA) and the Civilian Conservation Corps (CCC). A primary function of these two groups was to construct drainage channels. In 1944, the formation of Conservation Districts further addressed statewide drainage problems. These Districts, with help from the Soil Conservation Service, provided construction equipment, cost-sharing benefits, and technical assistance for survey and design. A significant effort in the reconstruction of drainage channels took place after Public Law 566, known as "The Watershed Protection and Flood Protection Act," was passed in 1954.

Over 200 years of channel work has established a basic drainage system throughout the State. However, maintenance of these systems for most of this time was not formally addressed, and, at best, took place voluntarily. As a result, the condition of the channels has slowly deteriorated due to sediment accumulation and vegetation overgrowth in the channels, and obstruction caused by fallen trees.

2.6.10.2 Tax Ditch Organizations

The Delaware General Assembly enacted the 1951 Delaware Drainage Law to establish ditch companies and to resolve related financial and maintenance issues. As an outgrowth of this Law, the Division of Soil and Water Conservation (the Division) is mandated to carry out a comprehensive drainage program through Title 7, Chapter 41 of the Delaware Code - Drainage of Lands: Tax Ditches.

A tax ditch is a governmental subdivision of the State. It is a watershed- based organization formed by a prescribed legal process in Superior Court. The organization is comprised of all landowners (also referred to as taxables) of a particular watershed or sub-watershed.

Formation of a tax ditch can only be initiated by landowners that petition Superior Court to resolve drainage or flood protection concerns. Governmental agencies do not initiate the formation process. This petition action results in the Conservation District requesting an investigation by the Division to "determine whether the formation of the tax ditch is practicable and feasible, and is in the interest of the public health, safety and welfare." If so determined, the Conservation District files the petition in Superior Court, and a Board of Ditch Commissioners (as directed by the resident judge) prepares a report on the proposed tax ditch. This report contains all required information per Title 7, Chapter 41, and is the basis for a hearing held for the affected landowners. At the conclusion of the hearing, a referendum is held for the landowners to approve or disprove formation of the tax ditch. The Board of Ditch Commissioners files the results of the hearing and referendum in Superior Court, and the Court holds a final hearing for any person to object to the formation of the tax ditch. Following the outcome of the final hearing, and if deemed appropriate, the Superior Court judge issues a Court Order establishing the tax ditch organization. The Court Order grants permanent rights-of-way to the tax ditch organization for construction and maintenance operations. It also empowers the organization with taxation authority to collect, from all affected landowners, funds to perform this construction and maintenance. Taxation amounts (ditch assessment base) for individual properties are also established through the Court Order.

Ditch managers and a secretary/treasurer oversee operation of a tax ditch. These officers are landowners within the watershed, and are elected at an annual meeting by the taxables.

To date, 228 individual tax ditch organizations have been formed throughout the State. These organizations range in size from the 56,000 acre Marshyhope Creek Tax Ditch to a two-acre system in suburban Wilmington. These organizations manage over 2,000 miles of channels and provide direct or indirect benefits to approximately 100,000 people and almost one-half of the State-maintained roads. *Map 2.6-2 Drainage Ditch Areas* shows the extent of these orfanizations in the Delaware Bay and Estuary Basin.

Tax ditch channels range in size from approximately 6 to 80 ft wide, and 2 to 14 ft deep. Size variation is due to the number of acres that drain to a particular site, and the topography of the area. For example, channels constructed through higher areas will be deeper than those going through lower areas. Generally, the more acres served by a channel, the wider it will be. In addition, the bottom "grade" of a channel and the degree of drainage required in an area will necessitate fluctuations in size.

Although tax ditches directly resolve many drainage and flooding problems, their primary purpose is to establish channel outlets for drainage and flood protection. From these channel outlets, individual landowners can construct private channels for use in management of their lands, and for implementing various best management practices for conservation.

Dependable drainage and flood protection in the Delaware Bay and Estuary Basin is essential for the management of many resources. Approximately 16.3 percent of the tax ditch organizations within the State are located in the Basin. Within the Basin, there are currently 39 tax ditch organizations containing approximately 99 miles of rights-of-way established for tax ditch management. These channels provide drainage and flood protection for approximately 20,000 acres, or 3.9 percent of the Basin area. It is estimated that an additional 2,000 miles of private channels exist throughout the Basin.

Tax ditches within the Delaware Bay and Estuary Basin have been organized and constructed utilizing the 1951 Delaware Drainage Law. These organizations are locally managed, with most following federally mandated operations and maintenance plans. Maintenance consists of routine vegetation control and sediment dipout. The condition of most of these channels is very good, although a few isolated organizations have not received adequate maintenance. In most of these isolated cases, negligence was/is mainly due to the original landowners dying, and the influx of new landowners to the area. In most cases, these new landowners are simply unaware of the negative impact of a failing drainage system.

Currently, there are several areas within the Basin where landowners have petitioned the court to form new tax ditch organizations to perform drainage projects. Small individual drainage problems have been solved in some of these areas through the public ditch program. In addition to tax ditch requests, the Division's Drainage Section also responds to requests for public ditches. Public ditches are generally smaller drainage systems that involve only a few mutually cooperative landowners. In the case of public ditches, landowners voluntarily grant temporary construction easements, usually to a Conservation District or a town/city. There are no provisions for perpetual maintenance by an organized group. The public ditches are planned utilizing the same best management practices used for tax ditches, constructed, and then left to the individual landowner's responsibility for future maintenance. Many isolated drainage problems have been resolved in the Delaware Bay and Estuary Basin utilizing this approach.

2.6.10.3 Environmental Concerns and Mitigation

The Division's Drainage Section is responsible for the formation, construction, and maintenance of Group Drainage Associations' tax ditches and public ditches. Historically, the planning and construction of water management systems has been accomplished with only administrative considerations from governmental agencies. The traditional program was a single purpose program (namely, drainage). Little consideration was given to environmental issues such as habitat or wetlands. As Delaware addressed clearly evident environmental concerns related to industrial and municipal discharge, development, and other areas, the environmental focus eventually progressed beyond these areas to other activities now recognized as also having potentially "significant environmental impacts". Drainage of lands through tax ditches is one such activity.

Various environmental groups and regulatory agencies began to question the potential impacts these projects were having on natural resources. For example, interpretation of the Army Corps of Engineers and State wetland regulations became a frequent, ongoing process used by groups in an attempt to halt or minimize projects. Regulatory exemption requirements for channel construction were tightened, and wetland/habitat mitigation was more frequently required.

Changes in the water management program were initiated in response to these environmental concerns and issues. Additionally, Governor Castle's Executive Order No. 56 mandated State agencies to achieve projects with a no net loss of wetlands. It is now recognized that natural resource impacts resulting from the reconstruction of drainage systems can and should be minimized. Weighing wetland concerns against drainage benefits prior to reconstruction of deteriorated channels has resulted in changes in procedures for selecting which channels to work on and what methods to use. For the past 10 years, numerous governmental agencies have performed a rigorous review process out of which comments are incorporated into related project plans. Ideally, these extensive reviews ensure that environmental impacts are minimized, or at least compensated for when deemed unavoidable. Implementation of this process over the last ten years has resulted in development of a detailed list of proven environmental practices that minimize impacts. This list has evolved into the Delaware Tax Ditch Best Management Practices (BMPs). Resource managers and planners on all water management projects routinely employ the BMPs. Some of the more significant practices include the following:

- Minimize clearing widths;
- Relocate channels around sensitive areas;
- Perform only one-sided construction;
- Save trees within construction zone;
- Minimize construction of downstream outlets;
- Install berm along wetlands with side inlet pipes at or above biological benchmarks; and
- Block off old channels that drain only wetland areas.

To complement this effort, the Drainage Section has held wetland/environmental training sessions for both technical and administrative staff members.

The most significant environmental impact from channel construction is the fill and drainage of forested wetlands. Fill results from clearing operations and disposal of excavated materials. Drainage occurs when wetland areas are not protected from surface flow into the channel. Loss or alteration of these wetlands is compensated through the creation or restoration of freshwater wetlands, usually in marginal agricultural fields. During the past 10 years, adherence to planning principles, policies and conservation management practices has minimized environmental impacts, and provided long-term economic and environmental stability.

The Drainage Section has also carried oou several projects to test new construction techniques, and established demonstration/education sites. Most of the channel construction techniques emphasize minimal clearing and spoil disposal. The demonstration/education sites incorporate these new construction techniques with wetland restoration in adjacent agricultural fields. Several demonstration projects have been performed statewide, and have effectively shown that drainage and environmental quality do not have to be mutually exclusive. In addition, drainage channels essentially link upland farms, cities, industrial sites, etc. to receiving bodies of water. Although channels themselves produce very little nutrients or sediment, they do represent a transport mechanism for these parameters.

Sediment load in drainage channels usually represents a short-term problem that occurs during reconstruction or maintenance events. Once stabilized, within six months to one year after such an event, channels discharge minimal amounts of sediment and actually act as sediment traps as vegetative growth eventually covers the channel bottoms and side slopes. These short-term sediment load problems can be lessened if sediment traps and water control structures are added. Such practices slowdown water flow, and provide areas for sedimentation and nutrient uptake by plants. However, when water-control structures are used, a concern exists that phosphorus tied to the sediment trapped upstream of these structures may be re-suspended through saturation.

Resolution of nutrient/sediment problems within the Basin will hinge on controlling and managing the source of these nutrients through effective use of BMPs for land management in cities, agricultural fields, rural areas and industrial sites. For drainage channels themselves, increased usage of current and new BMPs for tax ditch construction and maintenance will assist in reducing sediments delivered by drainage channels.

Once tax ditch channels are constructed, maintenance is the primary function of each individual tax ditch organization. Maintenance consists of the routine control of vegetation within the rights-of-way, and the periodic removal of accumulated sediment in the channel bottom. Control of woody vegetation adjacent to and within the channel is needed to retain access to the channel for future dip-outs of sediment. Rotary mowers and boom-arm mowers have replaced traditional hand labor, utilizing tools such as bushaxes. Unfortunately, mowing machines are not selective and cut all vegetation, including shrubs and grasses that are desirable for wildlife habitat. Mowing is generally performed every other year on established channels.

The Drainage Section and Conservation Districts continually search for viable alternative methods for maintenance. Several attempts have been made to establish vegetative maintenance programs utilizing herbicide application. This method, which decreases maintenance frequency and promotes growth of desirable species, has had varying degrees of success and acceptance by the tax ditch community. Recent experimental attempts include the use of a "weed wiper bar." This machine applies herbicides to targeted species by a wiping bar and leaves most desirable species untouched.

An alternative to controlling vegetation along rights-of-way for dip-out purposes is to allow trees to fully grow in the channel and along the accessway. This alternative presents a serious access problem every 15 to 20 years, when sediment needs to be removed. The channel and access-way would have to be stripped of this large vegetation, with resultant significant soil disturbance and erosion. By contrast, maintaining vegetation at desired levels (i.e., at heights/densities where dip-outs can readily be performed) is a more preferred method, as minimal channel disturbance occurs during dipout. As practicable alternative techniques for maintenance are developed, they are slowly incorporated into tax ditch maintenance plans through educational and promotional efforts.

In pursuing further innovations, the Drainage Section has become increasingly more involved in David Rosgen's "Geomorphic" approach to streambank restoration and channelization. Geomorphic design concepts are based on the evaluation of local/regional streams to measure natural characteristics that promote channel stability. Where applicable, these natural characteristics are integrated into tax ditch channel designs. A demonstration project utilizing these concepts has been implemented as part of the Pratt Farm Water Management project. In this project, a floodplain and sinuous low-flow channel were constructed in a marginal agricultural field to replace the historic straight channel. This Geomorphic approach will require special conditions and very receptive landowners to be successful. The Drainage Section will continue to develop data for use in this initiative as opportunities arise.

2.6.10.4 Dredging of the Delaware Bay and Estuary

Dredging is the process of hydraulically or mechanically removing bottom sediments in waterways to create or maintain navigable channels for recreational or commercial boating purposes. In the Delaware Bay and Delaware Estuary, dredging takes on added significance as an effective method for replenishing and maintaining public recreational beach areas and state-owned wildlife areas along the coastline, as well as an effective method for controlling sediment deposits in marina basins and boat launching facilities.

The dredging of navigational channels, marina basins and boat launching facilities, and excavation of sand from offshore borrow sources for beach nourishment along the shoreline in the Delaware Bay, can have negative environmental effects. These include the physical alteration of bottom topography, the resuspension of bottom sediments that may contain toxic substances, and the destruction of benthic flora and fauna. These effects, however, are usually localized and temporary. For example, borrow areas dredged for beach nourishment projects usually fill in to original bay-bottom elevations within one year after dredging has ceased. Sediment and elutriate analyses performed on samples obtained from some of the project areas listed below have indicated a low potential for toxic impact to occur to benthic organisms or aquatic animals inhabiting the areas. Turbidity occurs primarily while the dredge is in operation. Within hours after dredging has ceased in a given area, water quality generally returns to ambient conditions as the suspended fines flocculate and settle out of the water column due to the high salt content in estuarine waters. It is important to note that dredge induced turbidity is usually less than turbidity levels created by natural processes such as storm events. In addition, benthic fauna tend to recolonize dredged areas within a period of several months to a year after dredging has occurred.

On the positive side, dredging removes accumulated sediments from waterways and provides a deeper and safer channel for boaters. Beach-nourishment projects replace sand lost from public beach areas along the shoreline as a result of coastal storm occurrences in addition to sand lost to background erosion. These projects also provide erosion and storm damage protection to public, commercial and private structures and infrastructure landward of the coastline. In addition, beach-fill projects restore valuable habitat for horseshoe crabs and migratory shorebirds.

Historically, dredging projects in the Delaware Bay and Delaware Estuary have been conducted by the U. S. Army Corps of Engineers (Philadelphia District), the State of Delaware and the New Castle Conservation District. Federally authorized waterways maintained by the Corps in this region since 1990 include the Murderkill River Entrance Channel between Bowers Beach and South Bowers, the Mispillion River Entrance Channel and Cedar Creek near Slaughter Beach, and the Roosevelt Inlet near Lewes. When deemed to be suitable, dredged material has been used to renourish eroded shorelines and public beach areas adjacent to each respective project site. State Dredge Program navigational maintenance projects conducted in this area over the last ten years include the Augustine Beach Boat Launching Facility, the Murderkill River Entrance Channel, the Mispillion River Breach Closure, the Mahon River and the Roosevelt Inlet. Beach-nourishment and dune-restoration projects conducted by the State during this same time period include Pickering Beach, Broadkill Beach, Kitts Hummock, Bowers Beach and the Ted Harvey Wildlife Area. Navigational maintenance projects conducted by the New Castle Conservation District in the Delaware Bay and Delaware Estuary since 1990 include the Augustine Beach Boat Launching Facility, the Delaware City Mooring/Marina Basin and the University of Delaware, College of Marine Studies Harbor in Lewes.

There is presently an initiative underway in the Department to address concerns relative to dredging activities throughout the State. The Delaware Coastal Programs section is coordinating the "Statewide Dredging Activity Analysis and Management Project." The purpose of this project is to develop and establish a framework where proposed dredging projects can be analyzed in a comprehensive, systematic manner in order to minimize environmental impacts while maximizing public benefits. The specific objectives of this endeavor are:

- To develop a policy that provides a clear outline and guidance for the identification of problems relating to dredging operations;
- To provide a consistent approach to testing and monitoring activities that ensures the State's concerns are adequately addressed;
- To identify the data requirements, the preferred dredging types, and options for beneficial uses of dredged material early in the process; and
- To provide a Desktop Information System that expedites project review and makes environmental information generated to review dredging projects available for use in other environmental initiatives.

2.6.11 DATA GAPS AND RECOMMENDATIONS

1. Ensure that statewide wetland mapping is conducted every 10 years.

2. Develop baseline wetland trends in Delaware Bay Basin at intervals of 5 years to identify areas that are losing wetlands due to urbanization and/or agriculture (or during 10-year mapping intervals, maximum).

3. By watershed within the basin, use a wetland characterization method to determine wetland functioning.

4. Establish existing wetland conditions by watershed throughout the Delaware Bay Basin to use in a larger Watershed Health Strategy. Identify then those watersheds in need of wetland restoration or enhancement and which watersheds have been impacted the most for wetland habitat protective measures. Coordinate information with other initiatives (forest protection, natural heritage).

5. Develop a pond management initiative regarding nutrient management. Examine current management approaches and develop a more effective, broad-based management approach. Educate pond managers and concerned public to the problems confronting the eutrophication in ponds.

6. Work with the Counties to establish protocol for discouraging development in sensitive areas.

7. Adopt statewide wetland mitigation policy (Land Banking).

8. Along with impoundment managers, develop proper management measures for coastal impoundments.

9. Establish a more flexible mitigation and compensation process; this would allow resource managers to properly manage and ensure conservation of water and wetlands resources.

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2.7 LIVING RESOURCES

2.7.1 INTRODUCTION

By the beginning of the 16th century, the land that would become the political entity known as the State of Delaware encompassed a region of outstanding natural diversity. Clear freshwater rivulets tumbled down rocky streams and rivers from the hills of the Appalachian Piedmont Plateau into the drowned Susquehanna and Delaware River Valleys. These river valleys broadened into two magnificent bays, the centers of two vast estuaries, bordered with productive coastal marshes, abundant with shellfish and waterfowl that isolated the intervening coastal plain lands into an elongated peninsula. The larger of the two estuaries, Chesapeake Bay, formed the western boundary of the Delmarva Peninsula, while the smaller of the two, Delaware Bay, receives river and stream water from much of eastern Delaware.

Today, following nearly 400 years of natural resource consumption and the conversion of habitats by an ever-increasing number of immigrants for agricultural, residential, and industrial purposes, Delaware's remnant natural areas (woodlands, rivers, swamps, and marshes) still provide a biological history of Delaware. Yet, these natural remnants are under continual, increasing and unprecedented new pressures from humans. This portion of the document will assess the current status of these living resources, measure their spatial change and trends, outline protection and restoration efforts, and suggest possible solutions to retaining a dynamic natural resource base for Delaware's future.

2.7.2 CHARACTERIZATION

In many ways, our living resources reveal more about the state of our environment than any other factor. Our native species are generally the first indicators of change or disruption. They experience first-hand the direct impact of habitat loss, degraded air and water quality, and competition from exotic species. In particular, studies of rare and declining species can play special roles as environmental indicators. These are often the species most sensitive to environmental change and habitat degradation, and hence can bring the first hints of environmental impact. The trick is in knowing how to observe and understand nature's messages.

For instance, a stream's invertebrate fauna tells volumes about the water quality in a tributary. Although not usually included as a standard water quality indicator, the diversity of freshwater mussels is an excellent tool for understanding the health of a waterway. Mussels are filter feeders, and hence are especially sensitive to the effects of sedimentation and pollutants. Furthermore, many mussel species require the presence

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of particular fish species onto which their larvae must attach to complete their life cycle. When native fish species decline because of loss of habitat, damming of streams, or introduction of non-native fish, mussels are often the first to feel the impact.

Changes in an area's avifauna can also illustrate the accumulated environmental changes that often proceed unnoticed. Steep declines in insectivorous forest birds may indicate the loss or fragmentation of mature forests in our area. Increased numbers of American robins are in some ways comforting after the scare of *Silent Spring* in the early 1960s, but are also, unfortunately, reminders that fields, pastures, roads, and mowed lawns have replaced most of what used to be forest. Similarly, the presence of increasing numbers of non-migratory Canada geese is largely a result of human changes to the landscape, and the intentional introduction of goslings, which have no motive or inclination to migrate. Ironically, these large numbers of "transplanted" geese can lull the uninformed into complacency about their environment when, in fact, migratory Canada geese are experiencing region-wide declines.

There have been a number of studies, both on-going and short-term, of the Delaware Bay and Estuary Basin's flora and fauna. Fish and waterfowl are probably the two best-studied groups of species. Annual waterfowl counts date back to 1955, with more than twenty years of species-specific counts (Whittendale, 1996). Fish species were inventoried for all of Delaware's major streams in 1988, and summarized in two reports funded by the Federal Aid in Fisheries Restoration Act (Shirey, 1988; 1991).

The Delaware Division of Fish and Wildlife's Nongame and Endangered Species Program has conducted ongoing studies of some of the Basin's rare and declining species. The Federally Endangered Delmarva Fox Squirrel, once found in the forests of Delaware, was extirpated from the entire state. Reintroductions have been moderately successful in eastern Sussex County.

The Delaware Natural Heritage Program (DNHP), part of the Division of Fish and Wildlife, conducts on-going inventories of natural communities as well as rare and declining species, (e.g., state and globally-rare plants, birds, insects, mussels, reptiles and amphibians). It maintains a database, both electronic and manual, of its findings throughout the state. The DNHP has never conducted a comprehensive review of the status of biodiversity in the Delaware or any of Delaware's Basins. But from data that have been collected, it is commonly accepted that an alarming number of species which were once common are now found at only one or two locations, or are extirpated entirely. Of the fifty states, Delaware has been estimated to have lost the highest proportion of its native flora (Kutner and Morse, 1996).

2.7.2.1 Emergence of Delmarva Habitats

The modern habitats of the Delaware Basin have their origins in the relatively recent past. Delaware's Coastal Plain Province is young by comparison to the Piedmont's 500 million to billion year old rocks. Built by depositions of ancient sediments over the last 150 to 200 million of years, the coastal plain has been repeatedly inundated and exposed by rising and dropping sea levels. These sediments were eroded from Piedmont and Appalachian highlands and deposited along the margin of the continent by the Delaware and Susquehanna Rivers when the ocean covered the peninsula. The last time this happened was during the Sangamon interglacial event when the ocean was thirty feet higher than today. Since the Sangamon ended, approximately 80,000 years ago, the peninsula has remained above sea level. In fact, when the Wisconsin Glacier advanced southward around the globe from the Arctic 25,000 years ago, it trapped so much of the world's water that the ocean dropped 300 feet below modern levels, perhaps doubling the modern dimensions of the peninsula. This sheet of ice approached as far south as mid-New Jersey, and greatly influenced the types of plants and animals that inhabited Delaware's coastal plain (Scott, 1991).

The cold air mass associated with the huge ice sheet covering the globe produced very cold, cloudy, wet weather over the peninsula. This pattern persisted until about 12,000 years ago when a dramatic warming trend and a melting ice sheet increased the levels of precipitation, and caused a rise in the ocean level that continues today. During this period, a shift in the peninsula's vegetation occurred. Tundralike grassland with scattered boreal species such as spruce had occupied the peninsula during the height of the glacial period. As the weather warmed, northern boreal forest with intermittent remnant grass openings covered the landscape. About 10,000 years ago, pine replaced spruce as the dominant species in this coniferous forest. Over the next two thousand years, hemlock became a major component on the peninsula, while oaks first began to appear in these moist, mesic (well-drained) forests. During this period, the extinction of the mammoth, mastodon, giant beaver, and other megafauna left a largely modern group of animals on the peninsula. The warm moist weather pattern continued for over 5,000 years until the peninsula supported dense mesic forest, with numerous areas of swamps. A drying trend began around 5,000 years ago in the mid-Atlantic, and peaked from 4,700 to 2,200 years ago (Custer, 1984). This xerothermic period had dramatic effects on the flora of the peninsula, bringing about an increase in drought tolerant oak-hickory forest, an eastward extension of prairie grasslands, and a reduction or loss of many mesic species, including hemlock. Also about this time, sea level rise slowed enough to allow the formation of the estuarine marshes in Chesapeake and Delaware Bays (Kraft, 1977). Once the dry trend was replaced by moister and cooler weather, a landscape similar to modern Delaware emerged.

The Delaware Basin's modern flora and fauna associations have existed in similar form on the peninsula for the last 2,000 years. The ocean is still rising, slowly shrinking the size of the peninsula, and demonstrating that weather patterns are constantly and inextricably linked to the future of the Delmarva Peninsula. But perhaps the quickest changes to the living resources in the Delaware Basin, and to the entire peninsula, have occurred over the last four centuries since the period of European contact with Native Americans.

2.7.2.2 Prehistoric Human Impacts

It was during the post-glacial period, possibly as far back as 15,000 years ago, when man first ventured onto the peninsula. These were a stone-age people that crisscrossed the landscape in search of food. All they left behind was their stone tools, although some attribute the extinction of the megafauna to these skilled hunters (Martin, 1984). But these people brought another tool with them, fire, which they frequently applied to the landscape to drive game, maintain wildlife pastures, and for other uses (Pyne, 1982). The introduction of anthropogenic fire, added to the much more infrequent natural fire regime, was a factor in shaping the modern Delaware Basin ecosystem. The introduction of fire favored fire-resistant species, such as the oak and pine, over hemlock and other fire-vulnerable species.

These people were hunter-gatherers and harvested resources provided by the land and water. The strongest and healthiest among them persisted in a time of rapid climatic and geographical change. By 6,000 years ago, their culture had been replaced by other Native American populations who learned to use and alter the environment to better meet their needs.

2.7.2.3 Historic Human Impacts

The woodland Native Americans, known as the Lenni-Lenape people, were estimated to live in the Delaware Valley by 1,400 years ago. As their culture evolved, they developed base camps in semi-permanent villages along tributaries of the Delaware River, above the head-of-tide, where water would be consistently fresh for drinking and bathing (Berger, et al., 1994). By 1,000 years ago, these villages were surrounded by agricultural fields and hunting grounds that were manipulated by the Lenni-Lenape. Over the centuries, these alterations ran the gamut from amnual hand clearing of forest for camp sites, villages, work areas, or small gardens, to burning the forest understory to facilitate agriculture for growth of forage plants for large herbivores and game animals (DiLorenzo et al., 1993; Berger et al., 1994). Lenni-Lenape villages were moved periodically, as resources such as good quality soil for growing crops, or wood for tool making or fuel were exhausted (Heite, 1988; Berger et al., 1994). Temporary sites have been discovered that were used for procurement of food or other resources. After crops had been planted, tribe members would travel to sites along the lower estuary to net and trap various fish species in the river, especially during annual spawning runs. The Lenape also harvested and dried clams and oysters from the shallow shores of the Delaware Estuary, long before the European colonists came from the "old world."

Once here in America, the Europeans had an advantage over the Lenape because they had larger vessels, better tools, and more efficient equipment to harvest the shellfish in deeper sections of the bay, where they could not. The Lenape could only collect the oysters and clams in the more shallow sections of the bay. They had small boats and simple tools for hunting and fishing such as fiber nets, knives, spears, and arrowheads that were chipped from stone. Specific sites were visited to collect flint or chert for tool and weapon making (Berger et al., 1994). These Native Americans were a woodland group of people that spoke the Lenni-Lenape language (linguistically part of the Algonquin language), and lived in the forested sections of the Delaware Basin. The only major environmental change implemented by the Lanape was the periodic burning of the forest floor to clear land for agriculture and possibly to improve habitat for white-tailed deer and other game animals (Berger et al., 1994; Kraft 1988).

Dutch, Swedes and Finns were the first European settlers in the estuary, arriving during the first decades of the 17th century (Berger et al., 1994). The Dutch established a trading post in 1623; a whaling colony was established near Lewes in 1631 only to be destroyed by Native Americans in 1632 (Heite, 1988). The first Swedes and Finns arrived in the 1640s. One of the first settlements was in the vicinity of the Christina River and Tinicum Island. These people were farmers, raising grain and livestock and some tobacco (Berger, et al., 1994). Europeans began the process of changing the landscape from one of unbroken woodlands to a mix of agricultural fields and woodlots. The successful introduction of European agricultural practices meant not only a conversion of a significant percentage of forest to agriculture and pasture, but the extermination of predators, and the over-harvesting of game and furbearing animals. Beaver had been trapped out with the first fur traders in the 17th century. Great flocks of passenger pigeons had once returned annually to a "pigeon-roost," or breeding place, in the great oak groves of the Moyamensing, the Native American descriptive word for an unclean place or dung-heap (Scharf, 1888). The huge flocks of pigeons quickly disappeared from Delaware with the cutting of the trees, long before the species became extinct in 1914. Numerous species were exterminated from Delaware near the end of 19th century, including eastern gray wolves, eastern cougar, and black bear. Wild turkey populations fell to logging practices and market hunting by 1880, but were later reestablished. Whitetail deer were essentially gone from Delaware by 1900. In fact, deer hunting was illegal in Delaware for over 150 years, until the 1950s.

William Penn, and Englishman and a Quaker, arrived from England in 1682 to found the Pennsylvania colony in the Delaware Estuary region. Penn came ashore in on the west bank of the Delaware River, near Dock Creek in what is now known as the Society Hill section of Philadelphia. This was formerly a Lenape camp-site and where the Swedes had built a tavern, the Blue Anchor (Berger et al., 1994). The community of Philadelphia had 5,000 residents by the year 1700, quickly surpassing previously established towns in population and importance. Philadelphia was a community of merchants and tradesmen, and its economic vitality set the tone for the development of the entire region (Heite, 1988). During the 18th century, the lands of the Delaware Estuary were developed to meet the needs of city inhabitants. Forests were developed into farms, towns were built that organized the area's residents and caused the demand for timber, minerals, and farm products (Berger, et al., 1994). During this period, the Delaware Estuary became a major producer of wheat. Farming practices were unsophisticated; little care was taken to maintain soil fertility or to rotate crops, because these management practices were poorly understood at this time. A farm that yielded 20 to 30 bushels of wheat per acre in 1700 was only producing 10 bushels by 1730 (Berger et al., 1994). During this period in the country's development, it was more profitable to abandon the land and move on, rather than attempt to restore the soil's fertility (Berger et al., 1994). In the early 19th century, agricultural production had fallen. Many farms were abandoned in the 1820s and '30s when farmers left for better lands to the west of the mountains (De Cunzo and Catts, 1990). Although these abandoned, played-out farms could no longer support 19th century farming practices, they quickly developed young healthy secondary forests of loblolly pine. Still, by 1880, between 75 and 90 percent of each county was farmland. Virtually every upland habitat had been cleared. This practice had been driven in part by the arrival of the railroad. By 1890, Sussex County produced peaches, corn, and enormous amounts of strawberries (By 1900, Sussex County led the nation in strawberry production).

Changes within the estuary's waterways were at least as profound as those on the shore during the same period. Most were a direct result of changes that occurred on the land. Erosion due to agricultural land clearing, water quality degradation due to pollution discharge, shoreline manipulation for agriculture, and shore-based port facilities are all examples of changes that drastically altered the estuary (Sage and Pilling, 1988; Berger et al., 1994). Clearing of land for agriculture washed an enormous amount of topsoil into the estuary, changing the bottom topography dramatically, especially at the mouths of tributaries (Berger et al., 1994). Before the end of the 17th century, many boat landings had to be abandoned due to the siltation (Heite, 1988). This loss of topsoil was irrevocable. Shorelines, including tidal marshes, were diked for agricultural purposes and filled for port and industrial development during this period. Much of the pristine brackish and freshwater tidal marsh was lost in this way (Berger et al., 1994). Water pollution problems first began in urban centers where population was highest and industry prevalent. Pollution problems would escalate through the 18th, 19th and the beginning of the 20th century.

In the 19th century, a decentralization and diversification of industry due to the development of water-operated mills occurred (Heite, 1988). Flour, textiles and gunpowder were among the goods manufactured in mills across the region. Impounded lakes formed the head of power for mills across the Delaware Basin. These mills lacked the power of some mills in the Piedmont region and mostly ground grain into flour, co-existing with the farms of the basin. Farmers could work in the mills during slack periods and sell surplus produce to mill workers (Berger et al., 1994). The pace of life and the rate of change quickened considerably with the arrival of the railroad in the early 1800s. The beginning of our culture's reliance on fossil fuels and demand for rapid transportation to all sites increased both the pace and scope of industrial development along the river (Heite, 1988; Berger et al., 1994). The increase in industry escalated pollution problems that had begun in urbanized areas as early as 1690 (Berger et al., 1994). Waste and by-products from all waterside industries were dumped indiscriminately into the Delaware River. Wastewater from the burgeoning human population also ended up in the river and its tributaries. By the late 1800s pollution in the river was causing episodes of typhoid, but construction of wastewater treatment facilities in the early 1900s cut the incidence of this disease by 90% (Albert, 1988). Treatment of the problem rather than the source, however, would come later, and serious efforts to treat sewage effluent before it was dumped into the river did not begin until after World War II (Berger et al., 1994). The pollution of the water drastically affected aquatic and terrestrial life in and along the river of the long-term.

By the 1930s, an oxygen block was developing in the river, a region where levels of dissolved oxygen in the water were too low to support life due to the high oxygen demand of the waste. Over-fishing, coupled with the effects of dam construction, habitat destruction, and the oxygen block nearly destroyed the shad fishery in the Delaware Estuary (Price and Beck, 1988; Sage and Pilling, 1988). Clean-up efforts began in the 1930s, but experienced set-backs during World War II, before new sewage treatment plants opened in the 1950s. Dissolved oxygen levels rose slightly in the early 1960s, and septic conditions in the river were gone, but it was still heavily polluted (Albert, 1988). Efforts headed by the Delaware River Basin Commission began to reduce many discharges with waste load allocations. These efforts began to pay-off in the 1970s and 1980s as fish populations started to recover and the river once again saw recreational use (Albert, 1988; Berger et al., 1994). By 1995, most discharges were being processed and purified before release.

2.7.2.4 Biotic Communities

The following Delaware Natural Heritage Program (DNHP) descriptions summarize the natural communities found within Delaware Bay and Estuary Basin. Because the Basin ranges extensively from north to south, it includes a significant transition zone where a number of northern plant species reach their southern limits of natural distribution, while an even greater number of southern species reach their northern distribution limit. Despite the low elevations and generally simple topography throughout the Basin, a wide assortment of habitat types harbor a diverse flora and fauna.

The Delaware Basin is home to a variety of important forest communities that are found as repeating units on the landscape. These forests would fall within the broadly classified Mixed Mesophytic Forest Region in the northern portion of the Basin and gradually transitioning in the south to the Oak-Pine Forest Region (Braun, 1950), or the Oak-Pine-Hickory Forest Sub-Region, according to Greller (1988). In general, the northernmost forests in the Delaware Basin are comprised of a mixture of hardwoods, primarily being dominated by oaks, beech, tulip poplar, and hickories on the drier sites. The predominate tree species in a wide variety of wetland habitats include box elder, sycamore, sweet gum, slippery elm, red maple, tulip poplar, ash, pin oak, and sometimes river birch and black willow. The further south one travels in the Basin, a transition in forest species begins, but nowhere is this more dramatic than as one enters Sussex County. Here, the deciduous hardwood dominated forest gives way to an evergreen forest with a distinctive southern feel. This is the Oak-Pine Forest Region.

Two major components have been virtually eliminated from both of these forest types. American chestnut (*Castanea dentata*) and, to a lesser degree, American elm (*Ulmus americana*) were formerly important components of both of these forest regions, but have been virtually eliminated by the introduction of chestnut blight and "Dutch" elm disease. A new threat, anthracnose fungus (*Discula destructiva*), that attacks flowering dogwood (*Cornus florida*) is predicted by some to wipe out this significant understory tree from Delaware forests in the near future.

At one time, except for the tidal marshes, the Delaware Basin was virtually entirely forested. Native American fire practices opened park-like gaps within the forest, and altered the upland composition of the forest. Consequently, over the thousands of years of use, burning favored fire-tolerant species such as oak and pine over maple, beech, and hemlock. When European colonists arrived, they cleared the land with incredible speed relative to their numbers. They permanently fragmented and isolated the forest into small, scattered woodlots. The first areas to be cleared were upland forest habitats. These areas provided the best-drained farmland and easy accessibility. As a result, intact, old growth, upland coastal-plain forest probably no longer exists in Delaware. At first, the colonists avoided swamps and other wet forestlands. These forests were protected by their waters, which had also generally insulated them from Native American fires for millennia. But even these forests could not avoid the ax. In a trend that continues today, forests too wet to farm are regularly used for wood supply, livestock, hunting, and timber products. Many have had their hydrology altered by successful (and even unsuccessful) attempts at drainage. Many of the forested stream corridors in the Delaware Basin have been dammed, dredged, or have been used for irrigation. Still, somewhat amazingly, after the consistent and resourceful efforts to utilize these forests, a variety of wetland forest types remains.

However, because of their heavy utilization for over 200 years, there is tremendous variability in the quality of these forests. In all probability, the woodlands throughout the Delaware Basin are second, third, or even fourth growth forests, most with trees less than 50 to 100 years old. Because of these repeated disturbances, many forest-dependent plant and animal species in Delaware are threatened with extirpation. The greatest loss of species throughout the State has occurred in forested habitats. Yet, a few of the oldest trees in the State are found in this Basin, most occurring in wetlands. Although the age of these magnificent trees is unusual in Delaware, many of these huge plants are just reaching middle-age. Although the term "old growth" is frequently used to describe patches of forest containing these large specimens, a true, virgin, old-growth forest is not likely to remain in the Delaware Basin. However, some of these mature forest patches are developing some of the typical characteristics of an old-growth forest.

Nearly 75 percent of the Delaware Basin's terrestrial forests are no longer extant, having been cleared long ago for farm land and early settlements, or more recently for urban sprawl. Most of the remaining forests throughout the Basin are young successional woods, or maturing forests that are comprised of a high proportion of pioneer tree species that quickly reforest abandoned farmland or timber clearcuts. A significant transition from loblolly pine forest to red maple and sweet gum forests occurred during the 1960s and 70s as a result of clear-cutting second and third growth loblolly pine forest (Ferguson and Mayer, 1974). Twentieth-century forest practices that encouraged planting loblolly pine seedlings and suppressing hardwood competition with herbicide and mechanical means has lead to an increase in timber plantations and a further reduction in structural and functional forest diversity.

The following are brief descriptions of the community types that one is likely to encounter in the Delaware Basin along its entire length in Delaware (Bowman, 2000):

2.7.2.4.1 Upland Communities

Beach & Dune Communities

Maritime Red-cedar Woodland, Wax-myrtle – Groundsel-tree Maritime Shrubland, Bayberry – Beach Plum Maritime Shrubland, Beach Heather Dune Shrubland, Beach Foredune.

Upland Forests

Tuliptree Rich Wood, Coastal Plain Variant , Mesic Coastal Plain Mixed Hardwood Forest, Dry Oak – Heath Forest, Chestnut Oak – Hairgrass Forest, Mesic Coastal Plain Oak Forest, Loblolly Pine – Mixed Oak Upland Forest, Red Maple – Sweetgum Upland Forest, Loblolly Pine Plantation.

2.7.2.4.2 Non-tidal Wetlands Communities

Forested Wetlands

Forested Floodplains & Riparian Swamps
Red Maple – Green Ash Floodplain Forest, Black Ash Seepage Swamp, Pin Oak – Red Maple Floodplain Depression , Red Maple – Sweetgum Streamside Swamp, Delmarva Atlantic White Cedar Swamp, Atlantic White Cedar – Mixed Herb Bog, Atlantic White Cedar – Seaside Alder Woodland.

Isolated Forested Wetlands:

Coastal Loblolly Pine Wetland Forest, Wet Loblolly Pine Forest, Sweetgum – Red Maple Depression Swamp, Pin Oak – Sedge Swamp, Willow Oak – Basket Oak Swamp, Loblolly Pine – Mixed Oak Wet Forest, Loblolly Pine – Sweetgum – Red Maple Swamp.

Non-forested Wetlands

Shrub Swamps
Buttonbush Shrub Swamp, Water-willow Shrub Swamp.

Coastal Plain Ponds

<u>Coastal Plain Pond Buttonbush Communities</u>: Buttonbush – Walter's Sedge Coastal Plain Pond Vegetation, Buttonbush – Mannagrass – Smartweed Coastal Plain Pond Vegetation, Buttonbush – Warty Panicgrass – Eaton's Witchgrass Coastal Plain Pond Vegetation.

<u>Coastal Plain Pond Herbaceous Communities</u>: Three-way Sedge – Canada Rush Coastal Plain Pond Vegetation.

Streamside Herbaceous Wetlands

Streamside Tussock Meadow, Bulrush Deepwater Marsh, Cattail Marsh, Phragmites marsh.

Peat Wetlands

Yellow-eyed Grass Floating Peat Mat.

Aquatic & Submerged Vegetation

Water Lily Aquatic Wetland, Mixed Species Submergent Vegetation.

2.7.2.4.3 Tidal Wetland Communities

Freshwater Tidal Wetlands

Red Maple – Ash Tidal Swamp, Smooth Alder – Silky Dogwood Shrub Swamp, Wild Rice Freshwater Tidal Marsh, Mixed Forb Freshwater Tidal Marsh, Broadleaf Pondlily Freshwater Tidal Marsh, Arrow-arum – Pickerelweed Freshwater Tidal Marsh, Horned Pondweed Submerged Vegetation.

Saltwater & Brackish Tidal Wetlands

Salt Shrub, Salt Panne, Spartina Low Salt Marsh, Spartina High Salt Marsh, Common Threesquare Tidal Marsh, Smooth Cordgrass – Lilaeopsis Brackish Marsh, Giant Cordgrass Tidal Marsh, Switchgrass Tidal Marsh, Smooth Cordgrass – Water Hemp Tidal Marsh, Water-hemp Brackish Marsh, Cattail – Rosemallow Brackish Marsh, Bishop-weed – Mixed Species Brackish Marsh, Submerged Widgeon Grass Community, Phragmites Tidal Marsh.

2.7.2.4.4 Rare Community Types

The DNHP, in an ongoing process of describing and classifying natural communities within Delaware, located and mapped several unique and significant community types in the Delaware Basin (McAvoy and Clancy, 1993). *Map 2.7-1 Living Resources* shows these locations along with other natural areas.

Bald Cypress Communities

The DNHP considers naturally occurring bald cypress (*Taxodium distichum*) to be a rare species in the State of Delaware, including the Delaware Basin. This tree species has a relatively limited distribution and is found in only four watersheds in the state, only one of which is in the Delaware Basin (Murderkill River). The tree has a low number of natural occurrences within Delaware, where it reaches the northernmost limit of its North American range.

Bald cypress wetland communities are principally found on the forested floodplains of rivers and creeks that are temporarily and seasonally flooded. These wetland communities are considered to be climax communities in Delaware because of their extensive canopy coverage, large size and potential life span. On floodplains, bald cypress is rarely found growing in pure, mono-specific stands. It is typically associated with a mix of hardwood species, such as red maple (*Acer rubrum*), black gum (*Nyssa sylvatica*), sweetgum (*Liquidambar styraciflua*), and green ash (*Fraxinus pennsylvanica*). The James Branch and its tributaries in the Chesapeake Basin contain the most extensive and finest examples of bald cypress wetlands in the State (McAvoy and Clancy, 1993). The cypress communities in the Delaware Basin occur in both tidal and non-tidal wetlands within the Murderkill River watershed (McAvoy and Clancy, 1993). The cypress-hardwood association may be indicative of a short hydroperiod, because most other tree species can not have their roots submerged for extended periods of time. This is clearly demonstrated where floodplains have been dammed, creating ponds. The only trees still surviving in these ponds are bald cypress. Bald cypress trees are adapted to pro-longed flooding that would exclude other tree species. Some conifers such as Atlantic white cedar (*Chamaecyparis thyoides*) and loblolly pine (*Pinus taeda*) may also be associated with bald cypress wetlands.

The shrub and herbaceous layers of these floodplain wetlands are very diverse. However, the species found in these wetlands are often also common to hardwood floodplain wetlands as well. According to McAvoy and Clancy (1993), the bald cypress floodplains were not found to contain rare species outside of the bald cypress itself.

Atlantic White Cedar Communities

Atlantic white cedar (*Chamaecyparis thyoides*) is a wide ranging, but uncommon tree species found in a narrow interrupted belt scattered along the Atlantic coast from Maine to Florida, then west along the Gulf coast to Mississippi. The historical distribution of Atlantic white cedar on the Delmarva Peninsula is reported to be either very sketchy or limited. According to Dill and others (1987), Atlantic white cedar exists today on the Delmarva Peninsula in remnant stands that represent only a fraction of the species' former geographic and ecologic importance.

The many uses of Atlantic white cedar and its commercial exploitation are well documented in the literature (e.g., Little, 1950; Frost, 1987; Zampela, 1987; Laderman, 1987). Since colonial times, this tree has been logged repeatedly. Because the wood was lightweight, easily worked, and resistant to decay, it had many uses during the colonial period. Many Atlantic white cedar stands have been logged two, three, or more times in the past, not surprisingly making the tree a minor element in the landscape today.

Significant remaining populations of Atlantic white cedar in the Delaware Basin occur in six watersheds or sub-watersheds (Broadkill River, Primehook Creek, Slaughter Creek, Misipillion River, Murderkill River, and St. Jones River). An historical locale for Atlantic white cedar exists in New Caste County east of Taylors Bridge. Formerly, this was an extensive freshwater swamp that "changed in character literally overnight when, during a hurricane in the fall of 1878, a tidal wave breached the barrier beach in four places, inundating the Cedar Swamp" (Fleming, 1978). This swamp is now almost entirely salt marsh.

In its natural range, Atlantic white cedar is typically found along creeks and rivers, (Laderman, 1987). In Delaware, it formed dense stands at the headwaters of colonial period millponds in portions of Kent and Sussex Counties. Atlantic white cedar wetlands occur on very poorly drained, highly organic acid soils. These soils are described as muck-peat and range in thickness from a few inches to many feet. The cedars occur on hummocks of organic matter, leaf litter, and developing soils, surrounded by hollows that are flooded for lengthy periods of time (McAvoy and Clancy, 1993).

Where Atlantic white cedar forms pure stands, typical associated understory species include: Collin's sedge (*Carex collinsii*), sweet pepperbush (*Clethra alnifolia*), inkberry (*Ilex glabra*), Virginia willow (*Itea virginica*), spicebush (*Lindera benizoin*), sweet bay (*Magnolia virginiana*), partridge berry (*Mitchella repens*), golden club (*Orontium aquaticum*), swamp azalea (*Rhododendron viscosum*), greenbriars (*Smilax laurifolia* and *S. walteri*), sphagnum moss (*Sphagnum spp.*), highbush blueberry (*Vaccinium corybosum*), arrowood (*Viburnum dentatum var. lucida*), and possumhaw (*V. nudum*). Generally, except where openings occur in the cedar canopy, the overall floral diversity is lower in these swamps than in mixed white cedar/ hardwood swamps. However, these openings often harbor a plethora of rare species (McAvoy and Clancy, 1993).

Where Atlantic white cedar is not the dominant canopy species and co-occurs with other tree species (most notably, red maple, green ash, and black gum) there tends to be greater diversity of shrubs and herbs in the understory. In addition to the species mentioned above that are found in a pure Atlantic white cedar community, these woody species are commonly found in a mixed cedar-hardwood swamp: seaside alder (*Alnus maritima*), red chokeberry (*Aronia arbutifolia*), persimmon (*Diospryros virginiana*), strawberry bush (*Euonymus americanus*), American holly (*Ilex opaca*), winterberry (*Ilex verticillata*), fetterbush (*Leucothoe reacemosa*), sweetgum, tulip poplar, wax myrtle (*Myrica cerifera*), mistletoe (*Phoradendron flavescens*), loblolly pine, Virginia pine (*Pinus virginiana*), and greenbriar (*Smilax rotundifolia*) (McAvoy and Clancy, 1993).

Atlantic white cedar wetlands in Delaware and throughout their range are considered refugia for both State and globally rare species.

Coastal Plain Pond Communities

Coastal Plain ponds (also known as Carolina or Delmarva bays, whale wallows, etc.) are characterized as shallow elliptical or ovate variable-sized depressions oriented in a southeast-northwest direction. However, in Delaware, coastal plain ponds are usually less than an acre in size, and may or may not have the southeast-northwest orientation. Frequently, a pronounced sand ridge may be on the southeast side of the pond. A prominent rim circumscribing the pond is also a common characteristic, although not always present. Most of the ponds in Delaware are located in northwest Kent County and southwest New Castle County, although there are scattered ponds in other parts of these counties.

The origin of coastal plain ponds is a mystery. The ponds occur in the sand soils of the Atlantic Coastal Plain, from New Jersey to Florida, and are positioned on several different geological formations (Prouty, 1952; Gamble et. al., 1977). On the Delmarva Peninsula, the coastal plain ponds occur on the Wicomico, Talbot, and Pamilico terraces, between sea level and 90 feet elevations, and in the Pennsauken and Calvert formations (Rasmussen, 1958; Pickett and Spoljaric, 1971; Benson and Pickett, 1986; Stolt, 1986; and Stolt and Rabenhorst, 1987). At the present time, there is no accepted explanation of coastal plain pond formation.

Soil studies of coastal plain ponds in Maryland indicate the soils have low pH values (from 3.6 to 4.6); are poor to very poorly drained; and range from silt loam to silty clay loam at one extreme, to loamy sand at the other (Stolt and Rabenhorst, 1987). Coastal plain ponds in Delaware have similar textural characteristics as the Maryland coastal plain ponds. Most coastal plain ponds are characterized by fluctuating water tables, and are mainly derived from ground-water recharge in the winter. As a result of ongoing biological surveys by DNHP staff, it is surmised that these fluctuating water tables contribute to the establishment of much of the unique herbaceous flora, while often precluding establishment of most woody species, such as shrubs and trees. Moreover, DNHP estimates that as a result of anthropogenic activities (subdivisions, channelization, etc.), more than half of the known coastal plain ponds have been destroyed or have severely disrupted hydrology.

According to a 1993 DNHP survey, the majority of the coastal plain ponds in Delaware are degraded. Impacts to the ponds resulted from perturbations of the local ground-water supply due to clearcutting of adjacent forest habitat, channelization of natural streams, and ditching to drain nearby agricultural lands. These activities are thought to have altered the environmental character of these systems by disrupting the surficial and subterranean water supply, and affecting water quality of the ponds.

Coastal plain ponds are important to preserve and protect. They are critical refugia for a variety of endangered species of animals and plants, and are geologically unique entities with no definitive origin. They provide a unique and local habitat for the Delmarva Peninsula complex of flora and fauna. They are important for local ground-water recharge to maintain adequate drinking water and baseflow for streams. Efforts to protect these wetlands via acquisition, public outreach programs, or regulatory protection will be necessary if we are to preserve this unique resource.

2.7.2.5 Wildlife

2.7.2.5.1 Game Populations

There are 58 species currently classified as “Delaware game animals” and managed by the Division of Fish and Wildlife (F&W). Among these species are 44 birds, 11 mammals, 2 reptiles, and 1 amphibian. All of the mammals, reptiles and amphibians, as well as 6 bird species, are year round residents. The remaining 38 bird species are classified exclusively as migratory and fall under the jurisdiction of the U.S. Department of Interior.

The whitetail deer (*Odocoileus virginianus*) is native to the Delaware Basin and has adapted and thrived in the human altered habitat. Deer damage to agricultural crops has become a serious concern within Delaware. The Basin includes a few of the top deer management zones in terms of the number of crop damage complaints and severity of damage. Since 1992, the deer harvest within Delaware has continually increased, with some years significantly higher than others. The overall statewide increase during this time period averages 36 percent.

Because of its strategic location, the Delaware Basin and its wetlands and associated uplands are extremely important to waterfowl and other wetland dependent migratory birds in the Atlantic Flyway. The wetlands across the Basin are regionally small but when interconnected form a critical route for birds that migrate between and/or winter in the Delaware and Chesapeake Bays. For this reason, conservation agencies place the highest priority on the protection, restoration and enhancement of habitats that serve as wintering areas or reduce fragmentation of prominent migration corridors for migratory birds. The Delaware Basin provides unique habitat during migration for high priority species designated by the North American Waterfowl Conservation Act (NAWCA) which includes the Black Duck, Mallard, and Northern Pintail, and is a focus area for the Atlantic Coast Joint Venture.

Beaver (*Castor canadensis*) was apparently extirpated from Delaware by the mid-1800s. They were reintroduced to the State in 1935 with the release of 1 pair in each county. Since then, additional animals have moved in from Maryland, and repopulated. In 1943, the population was estimated at 24 animals. By the mid-1980s, the beaver was beginning to come into conflict with humans, primarily because of road and field flooding and destruction of trees. In 1990, F&W captured and relocated 28 problem animals in Sussex and southern Kent

Table 2.7-1 Turkey Harvest Statistics in the Delaware Basin

1991	1992	1993	1994	1995	1996	1997
74	57	47	39	43	40	78
1998	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
50	39	32	32	36	25	18

Note: 1991 – was the first hunting season reporting;
1997 – much more area opened to hunting in the basin;
Since 1997 – population seems to be dropping – reason(s) unknown.

Counties. A 1991 survey of beaver colonies found 126 statewide, with approximately 25% of those in the Delaware Basin. There is an active program to trap and relocate nuisance beavers to suitable sites. From 1997 - 2000, approximately 300 beaver per year were harvested statewide. Beaver populations are increasing within the Basin.

Like the beaver, the Wild Turkey (*Meleagris gallopavo*) was extirpated from Delaware by the mid-1800s. In 1984, 34 wild birds were brought to Delaware from New Jersey, Vermont, and Pennsylvania. Between 1989 and 1997, 107 turkeys were captured within the State and transferred to release throughout the state including the Delaware Basin.

Beginning in 1990, selected turkey management zones were surveyed for wild turkeys. Due to budgetary limitations, turkey surveys were not conducted after 1997. After turkey stocking efforts, populations did show a significant increase in numbers throughout the state. Since then, the only data collected are harvest success numbers. *Table 2.7-1* depicts the harvest success in the Delaware Basin of turkey and illustrates a decline. Over the past several years.

Wild turkeys are very adaptable and will use a variety of habitats from mature forests to open agricultural fields. The current mix of these habitats in the Delaware Basin makes the area good turkey habitat. Agricultural land provides an important winter food source in the form of waste grain. Forestland (especially forests with a significant oak component) provides food as well as nesting and roosting cover.

When Delaware residents think of Canada Geese (*Branta canadensis*), they generally think of the migratory flocks that come here from Canada in the fall. More and more, however, resident flocks that stay all year are becoming common. Resident flocks first became established in northern New Castle County, likely the result from releases of captive birds. Resident flocks are flourishing throughout the State, with hundreds of geese using small ponds, open space and parks scattered throughout the Delaware Basin.

Resident geese are becoming a problem in Delaware. In this Basin, geese have caused damage to lawns on residential and commercial properties. They litter areas with feathers and are sometimes aggressive toward humans. There have also been complaints concerning water quality in ponds used by large numbers of birds, as well as complaints concerning crop damage to young corn and soybean plants. Because of the abundance of agriculture and small ponds, resident goose numbers are expected to increase in the Basin. To date, methods for controlling resident geese have been largely ineffective. As the human population continues to build in the Basin, goose/human conflicts will likely increase as well.

The previous four game species are very adaptable and are, for now, doing relatively well in the face of human impacts on the land. The Northern Bobwhite Quail (*Colinus virginianus*) is, however, another story. This species is tied closely to, and dependent upon, early successional/grassland habitats. This type of habitat was common on the small family farms that once dotted Delaware's landscape. However, farm hedgerows that once provided escape cover for quail have been eliminated to accommodate more crops and the large equipment used for planting and harvesting. As a rule, crops are now planted to the woods edge, leaving no buffer strips of grasses or weeds. In addition, today's crop harvesting techniques are much more efficient than they used to be. As a result, the amount of waste grain left for quail has been reduced. Finally, the use of chemical pesticides and herbicides has increased over the years. All of these factors combined have caused a drastic decline in Bobwhite Quail numbers.

Due to the decline in Bobwhite Quail populations, F&W implemented random statewide quail roadside survey routes in 1995. Observers count the number of quail heard whistling along a standardized route. Data are then broken down to the

Table 2.7-2 Results of the Whistling Bobwhite Quail Survey

	1995	1996	1997	1998	1999	2000	2001	2002	2003	Avg.
New Castle	1.09	0.40	0.19	0.50	0.78	0.85	0.50	0.88	0.12	0.59
Kent	2.26	0.68	0.60	1.75	0.87	0.52	0.59	0.50	0.95	0.97
Sussex	1.32	1.86	0.67	1.82	2.27	1.64	0.78	0.63	0.48	1.27
State Totals	1.56	0.98	0.49	1.38	1.31	1.04	0.62	0.67	0.20	0.94

Note: The 2003 data are not statistically valid due to differences in routes surveyed, but do concur with general field observations and reflect the same historical trends.

number of quail heard per mile driven, and comparisons are made between years. Survey data demonstrate a drop in quail numbers since 1995 (*Table 2.7-2*).

The decline in Delaware Basin quail populations follows the State trend as a whole although there are six Wildlife Management Areas within the Basin where intensive habitat management resulted in high numbers of calling males. It is important to note that this Basin represents about one-third of the land area of Delaware including many of Delaware's towns and cities, however, many areas exist for continued habitat protection or restoration. The 1996 U.S. Farm Bill presents resource managers with perhaps the last best chance to stabilize or reverse the quail decline. Congress earmarks annual funding for programs that will enhance wildlife habitat and water quality as well as reduce soil erosion. The most significant program under this bill is the Conservation Reserve Program under which farmers and other landowners can take land out of production and receive annual payments for a 10 to 15 year period. In addition, the program will cost share up to 50 percent of the funding required to create and maintain wildlife habitat. Another program is the Wildlife Habitat Incentives Program that provides a one-time cost share of 75 percent to landowners who would like to implement projects for wildlife.

2.7.2.5.2 Non-Game Populations

The only information people generally receive about non-game wildlife populations is about the listed (rare) species. Many animal species are not threatened with extinction. In fact, some species have even benefited from the anthropomorphic changes to the landscape over the past 300 years (e.g., red fox, gray squirrels, and woodchucks have probably never been this common). Broad-spectrum habitat users such as American Robins, Blue Jays, and Ring-billed Gulls have far more available habitat now than they had before the major land-clearing efforts began. Brown-headed Cowbirds, Killdeer and other open country animals have taken quite well to the man-made expansion of the agricultural "prairies" and successional forest margins. Finally, due to its ability to thrive in a variety of habitats, the coyote may quite possibly be the latest animal to be observed moving into the state.

In contrast to the above "successes," too many non-game species of animals have had their habitats reduced significantly. These animals usually have narrow habitat requirements. The critical factor to the success or failure of a species could be available breeding or nesting habitat, foraging habitat, or direct competition for habitat with exotic or native invasive species. In many cases, these vital habitats have become isolated, decreased in size, or degraded in quality. Even the best habitats are vulnerable or threatened. Examples of this are breeding colonies of Great Blue Herons (*Ardea herodias*) which dot the landscape in mature forests throughout the state. All too often these colonies are pushed out of their habitat due to anthropogenic activity related to new development. Great Blue Herons are intolerant of human activity near their nest location. Lack of available nesting habitat is a potential limiting factor for this species in Delaware. Many of the Great Blue Heron colonies in Delaware are located within protected conservation lands. This is not accidental, but represents the only available nesting habitat left for this species.

One bastion for herons and egrets is Pea Patch Island located in the Delaware River, which is home to the largest colony of nesting herons on the East Coast (north of Florida). In 2002, Pea Patch Island Nature Preserve was dedicated as a Continentally Important Bird Area by the National Audubon Society, supporting the area's consideration as a wildlife resource of both local and national significance. The Preserve has significant populations of breeding pairs of nine species of wading birds: Great Blue Herons (*Ardea herodias*), Great Egrets (*Ardea alba*), Little Blue Herons (*Ergetta caerulea*), Snowy Egrets (*Ergetta thula*), Cattle Egrets (*Bubulcus ibis*), Yellow Crowned Night Herons (*Nyctanassa violacea*), Black Crowned Night Herons (*Nycticorax nycticorax*), Glossy Ibis (*Plegadis falcinellus*), and Green Herons (*Butorides virescens*). A rapid decline in nesting pairs of about 12,000 in the late 1980s to less than 3,000 currently resulted in the development of the Pea Patch Island Heronry Region Special Area Management Plan (SAMP). The SAMP outlined a broad, ecosystem approach to protecting and improving the resources that support the Pea Patch Island Heronry. Additionally, the SAMP will facilitate building knowledge about the heronry, and will ensure the commitments necessary for its long term protection. (DCMP, 2001)

Most forest species populations are in decline in Delaware. This should not be surprising when one understands that most of Delaware's forests have been reduced in area, connectivity and overall forest quality for over 300 years. Many bird species that once commonly bred in Delaware are now found infrequently, or they are briefly seen passing through during migration. The situation is even more troubling for the less mobile animals, fish, reptiles, amphibians, and invertebrates. The survival of these animals is critical because they represent a measure of the living resources of the state. The imperative identification and protection of natural areas that preserve this faunal diversity, which will also protect the floral diversity, is critical to keeping a healthy living resource base in the Delaware Basin, and throughout Delmarva.

For example, the Cerulean Warbler (*Dendroica cerulea*) is dependent on mature deciduous floodplain forests and surrounding upland forests for reproductive success. This species is now known to be breeding in fewer than six sites throughout Delaware, and is fairing poorly throughout its global range. Other bird species such as the Barred Owl (*Strix varia*), Redshouldered Hawk (*Buteo lineatus*), and Pileated Woodpecker (*Dryocopus pileatus*), are important forest predators that have disappeared from most of Delaware's woodlands. These species require extensive tracts of mature floodplain forests to ensure successful reproduction (Clancy and others, 1995). The populations of these birds, and many others, are also in decline in Delaware because of fragmentation and elimination of the surrounding upland forests.

The high diversity of insect species, particularly odonates (dragonflies and damselflies) was found to be reflective of the variety of wetland habitats found within the study area. The most notable species found were the blue-faced meadowfly (*Sympetrum ambiguum*), blackwater bluet (*Enallagma weewa*), and the blue corporal (*Libellula deplanata*) (Clancy and others, 1995).

In all of the Delaware Basin areas that have been inventoried, there are 67 aquatic animal species which have been ranked S1 (extremely rare with 5 or fewer occurrences), S2 (very rare with 6 - 20 occurrences), or SH (historically known, but not found for 15 years or more) (Delaware Natural Heritage Program Database, 1998). The list is comprised of 15 fish, 9 freshwater mussels, and 43 aquatic insects. These species, with depressed population numbers, are especially vulnerable to water-quality degradation and alterations in established food chains caused by the introduction and establishment of non-native species. Also, damming of rivers and their tributaries for millponds impedes the movement of some fish species which, in turn, impedes mussel larvae, which are dispersed by those fish.

There is a need for an inventory to determine abundance and presence of species in areas that have never been surveyed or in areas that have not been surveyed for 10+ years. Current data are incomplete regarding native minnows and freshwater mussels. Once identified, the locations of these populations need to be protected.

The Delmarva fox squirrel (*Sciurus niger cinereus*) is a sub-species of the Eastern fox squirrel. It was once a common inhabitant of forests on the entire peninsula. The species is found mostly in mixed stands of mature hardwoods and loblolly pine located along streams and bays. In some locations, squirrels occur in forest stands dominated by loblolly pines adjacent to salt marshes. Due to declines caused by loss of their forest habitat to development, timber harvest and forest conversion the Delmarva fox squirrel was placed on the Federal Endangered Species List in 1967. Naturally occurring populations exist only in four counties on Maryland's Eastern Shore. Animals have been reintroduced in Pennsylvania, Delaware and Virginia. Prime Hook National Wildlife Refuge is the site within the Delaware Basin of one of Delaware's introductions.

Although highly visible non-game species such as the Bald Eagle (*Haliaeetus leucocephalus*) have received a lot of attention, it was the protection of the Bald Eagle's habitat (and the elimination of DDT use) that protected both it and perhaps thousands of other species that share the eagle's foraging territory. Ultimately, it is the protection of vital identified habitat that will preserve Delaware's living resources and protect our biological history.

Shorebirds occur throughout the world and are a familiar sight to visitors and residents of our coastal shores and waterways. These remarkable birds have some of the longest migrations known, traveling from their wintering ground at the tip of South America to their Arctic breeding grounds and back again each year. Their migration also includes some of the longest non-stop flights in the bird world, commonly exceeding 1,000 miles (1,600 km). Stopovers like Delaware Bay play an important role by providing food resources for these birds at critical times during migration. Over half of the Western Atlantic flyway's population of red knot (*Calidris canutus*), ruddy turnstone (*Arenaria interpres*), and semipalmated sandpiper (*Calidris pusilla*) may rely upon the Delaware Bay in the spring to replenish their energy reserves before heading to their Arctic nesting grounds (USFWS, 2004). To accomplish such feats of migration endurance, shorebirds must have large amounts of fat for "fuel," but their wing size and muscle strength limit how much weight they can lift. Therefore, they must carefully balance their need for fuel with their ability to fly.

The world's largest spawning population of horseshoe crabs (*Limulus polyphemus*) occurs in the Delaware Bay. A single crab may lay 100,000 eggs during a season. While the crab buries these eggs deeper than shorebirds can reach, waves and other horseshoe crabs cause large numbers of eggs to rise to the surface. These "surface" eggs will not survive, but they provide food for many animals. The shorebirds are especially dependent upon these eggs, due to their need for an abundant predictable food supply. The birds stop at only a few places during their spring migration. At each stopover, they have only limited time to meet their food requirements before they must move on. Weather delays or reduced food supplies at critical stopovers can have significant effects on adult shorebird survival and breeding success.

Strandings of marine mammals and sea turtles have been documented in Delaware since the early 1960s; however, there was no official stranding program and reporting and response efforts were inconsistent. During the late 1980s, when hundreds of Atlantic bottlenose dolphins (*Tursiops truncatus*) stranded along the Atlantic seaboard, efforts to document strandings increased and an official stranding program was developed. Improved communication between agencies and groups increased the valuable data collected, although data prior to 1993 are inaccurate, the information can still be useful.

Historically, marine mammals and sea turtles that have been stranded in Delaware included 3 species of marine turtle, 4 species of seals, 6 species of dolphin or porpoise, and 11 species of whale (Stetzer, 2000). Mortality factors for sea turtles where cause of death could be determined resulted from mainly boat collisions and fisheries interactions (gillnet, trawl, longline, hook and line). Although the majority of seals are stranded alive, pinniped mortality seemed to derive from infections, parasitic loads, and upper respiratory diseases. Gill netting for striped bass and shad coincide with the presence of pinnipeds in the Delaware Bay and there are some reports of drowning in nets. Many dolphin, porpoise and whale strandings showed signs of boat impact with propellers, although a cause of death could not be determined on a high percentage of cetaceans based on decomposition. Strandings increase during the spring and fall gill netting season, and external net marks are evident on some of these strandings.

2.7.2.6 Fisheries Resources

2.7.2.6.1 Commercial Fisheries

The streams and rivers that drain into the Delaware Bay support many species of fish that are harvested for both food and profit. The majority of commercial fishing efforts take place in the Bay and the major rivers, with American Eel (*Angnilla rostrata*), American shad (*Alosa sapidissima*), Atlantic Menhaden (*Brevooritia tyrannus*), bluefish (*Pomatomus saltatrix*), and weakfish (*Cynoscion regalis*). However, other species have also shared this distinction and include Alewife (*Alosa pseudoharengus*), Atlantic Croaker (*Micropogonias undulates*), Blueback Herring (*Alosa aestivalis*), common carp (*Cyprinus carpio*), spot (*Leiostomus xanthurus*), striped bass (*Morone saxatilis*), and white perch (*Morone americana*). Fisheries management plans implemented by several state or federal agencies exist for all commercially harvested species ranging from those above to flounder, surf clam, sharks, tuna, and squid.

Striped Bass (*Morone saxatilis*) have historically been an economically valuable species, but at once reached low abundance requiring a moratorium. Fishing efforts are regulated via limited entry, landing quotas, seasons, size limits, gear restrictions and area closures. Despite these restrictions, some species have declined, are at low population levels, or at depressed historic levels. A combination of habitat loss, water quality degradation, and overfishing has contributed to this decline.

Historically, fisheries of major importance from the 1850s to the 1920s were those for Atlantic sturgeon (*Acipenser oxyrhynchus*), river herrings (blueback and alewife), and American shad. Over-exploitation and pollution were major factors in the crash of these fisheries in the early 1900s. A fisheries management plan for sturgeon is now in place although problems with spawning grounds in the upper river, and extended periods to maturity hamper fisheries recovery.

Several rivers in this Basin have been dammed to create ponds, which in turn impede anadromous species (such as alewife, blueback herring, and American shad) from reaching historic spawning areas. The Department is currently evaluating the impact of fish ladders installed on several dams in Delaware Bay tributaries. Once evaluations are completed, an anadromous species management plan will be drafted. At that time, recommendations will be made regarding tributaries of the Delaware Bay that impede migration of anadromous species.

Yellow perch (*Perca flavescens*) populations have had a steady systemwide increase in reproduction since 1993, and the lifting of current restrictions on commercial and recreational harvest in Maryland waters is being evaluated (Paul Piovis, Maryland DNR, pers. comm.). In the Delaware portion of this drainage, there are no special restrictions and no commercial fishery for yellow perch. Minimal data exist regarding current yellow perch populations and structure.

The American eel (*Anguilla rostrata*) is a species of special concern. This species utilizes the Delaware Bay drainage as a nursery and feeding area. Harvested eels never have an opportunity to spawn. There is a "black market" for elvers (i.e., eels less than 6 inches) which are illegally collected and sold in foreign markets for over $300/lb. The 6 - 12 inch juveniles are sold legally as bait and live food in U.S. and foreign markets. Currently, Delaware has no limit on the number of commercial licenses, no limit on the number of pots allowable per fisher, and no reporting requirements. An American eel management plan is available with more data being collected regarding fishing effort, landings, or stock size (John Clark, F&W, pers. comm.).

The Blue crab (*Callinectes sapidus*) inhabits nearshore coastal and estuarine habitats throughout the western Atlantic, Carribean and as far south as Ecuador (Helser and Kahn, 1999). Despite the fact that Delaware Bay is near the northern extremity of its range, blue crab catches currently produce the largest dockside value of any fisheries resources in Delaware. With an increasing demand for crab meat, coupled with declines of harvests in the Chesapeake Bay stock, efforts on the Delaware Bay stock have increased markedly since the mid-1980s. Very recent declines in landings and catch-per-unit-effort have raised concerns that these declines may foreshadow future stock depletion. This concern has led to the development of a bi-state fishery management plan.

The Surf clam (*Spisula solidissima*) is a large, commercially important bivalve, which inhabits polyhaline and euhaline environments from the ocean surf zone to a depth of about 140 feet. Surf clams inhabit only predominantly sandy or gravel bottom areas. Firm sand bottom is necessary to help keep the valves closed because surf clams have relatively weak adductor muscles. Surf clams require 5 - 6 years to reach minimum commercial size (4 ½ - 5 inches) and are fairly long lived (20+ years).

Exploitation of surf clam stocks is fairly recent. Beginning as a small bait fishery following World War II, the fishery expanded rapidly to satisfy demand for the more limited hard clam resources. Surf clams are generally processed commercially and sold as a canned or frozen product. By 1965, surf clams accounted for over 60 percent of all clam meats used in this country.

Surf clams range from southern Maine to Cape Hatteras, but are most abundant off the coast of the Delmarva Peninsula and New Jersey. In Delaware, commercial processing of surf clams began in the early 1950s, working on clams caught off New Jersey. The Delmarva stock of surf clams began to be exploited in 1966. Commercial landings peaked between 1970 and 1972 when they were harvested annually. Many of these clams came from sand shoals in state jurisdictional waters. Hen and Chickens Shoal, a large ebb-tide shoal near Cape Henlopen, produced surf clams worth millions of dollars in the early 1970s. Depleted by 1975, Delaware's inshore surf clam resource has not returned in commercial densities. Three surveys of surf clam habitat during the 1980s and early 1990s have shown almost no adult surf clams, although juveniles are common in benthic grab-surveys.

One concern regarding surf clams is that the prime habitat for this species, shoal tops and edges, be conserved until a viable commercial population can be reestablished. Presently, part of Hen and Chickens Shoal has been permitted by the U.S. Army Corps of Engineers as a borrow site for beach replenishment for Rehoboth Beach. The Corps commitment to this replenishment effort covers the next 50 years. Hen and Chickens Shoal is an ebb tide shoal at the mouth of Delaware Bay. Areas near Cape Henlopen are dynamic, being rebuilt by ebb tide currents. The extensive offshore areas, such as the permitted borrow site, are relic structures, built during fairly recent geologic time when the coastline was farther east and sea level was lower. Sand from relic shoals, once removed, will not rebuild and is permanently lost as surf clam habitat.

On November 1st, 2001, Delaware held its first Eastern oyster (*Crassostrea virginica*) season since 1995. This decision was made by the Division of Fish and Wildlife through their fisheries management process. The oyster disease MSX (parasite) and the oyster drill first turned up in the Delaware Bay in 1957. Through relayed shell, the disease quickly spread to the Chesapeake, and beyond. Both diseases are controlled partly by salinity, with lower salinities decreasing their impact. Since then, another oyster disease, Dermo (parasite), has turned up in U.S. waters including the Delaware Bay. Neither of these diseases are harmful to humans. However, many oysters succumb to them about the time they reach market size (3 inches – approximately 3 - 5 years). Unlike past harvests, Delaware's is utilizing the "direct harvest" approach. The typical and traditional means of harvesting oysters is to take them from public beds, then transfer them to lease beds further down the Bay. Typically, this resulted in up to 50% mortality of the oysters. The direct harvest has oysters going directly from public beds to the shippers to the consumer.

In July 1992, Delaware became the last Atlantic coast state south of New York to initiate an artificial reef program. Following an extensive planning period, reef development began in 1995 and will continue in the future. Reef development provides protective structure and trophic support to various species of structure-oriented fish, specifically tautog, black seabass, scup, trigger fish and Atlantic spadefish. Other gamefish, such as striped bass and weakfish, are attracted to baitfish which school around structures.

Delaware's reef program is defined in the Delaware Artificial Reef Plan. Materials must be durable, stable and non-toxic. Concrete, steel, derelict steel vessels, decommissioned military vehicles, and ballasted tire-units are presently being deployed. There are eight permitted sites in Delaware Bay and three in the Atlantic Ocean. More than 23,000 tons of suitable material, 86 decommissioned military vehicles, numerous subway cars, and two tugboats have been sunk on Delaware's reef sites.

Artificial reef development is especially beneficial to structure-oriented fish in the Mid-Atlantic region, where the bottom is normally featureless sand or mud. There is very little natural rocky habitat which is common in New England waters. Similarly, there are no biological reef-builders (i.e., corals) common in the southeast. Artificial reef development in the Mid-Atlantic region may allow an overall increase in some fish stocks, like the tautog, which may be habitat-limited. Delaware's artificial reef-building efforts (i.e., habitat enhancement) are just one part of a comprehensive fisheries management program which includes traditional management measures like controlling creel and size limits.

The Division of Fish and Wildlife presently monitors reef sites for permit compliance (side-scan sonar surveys), for biological productivity (invertebrate sampling), and to determine user effort (aerial boat count survey).

Compliance monitoring documents that all material is deployed within the perimeter of permitted sites and that sufficient clearance exists for navigational interests. Invertebrate sampling has documented that an entirely different community develops on reef structure, often with a biomass several hundred times greater than the native infaunal community. The

Table 2.7-3 Impacted Lakes and Ponds

Pond	Acres	Sub-Basin	Types of Nuisance Plants	Magnitude of the Problem
Abbotts Pond	17	Mispillion River	Hydrilla	Moderate
Andrews Lake	18	Murderkill River	filamentous algae	Moderate
Blairs Pond	29	Mispillion River	Hydrilla, filamentous algae	Moderate to Severe
Lake Como	42	Smyrna River	microscopic algae	Minimal
Coursey Pond	58	Murderkill River	filamentous algae	Minimal
Derby Pond	28	St. Jones River	algal mats	Minimal
Garrisons Lake	86	Leipsic River	Planktonic algae	Moderate
Griffith Lake	32	Mispillion River	Hydrilla, filamentous algae	Moderate to Severe
Haven Lake	82	Mispillion River	filamentous & planktonic algae	Moderate to Severe
Killens Pond	75	Murderkill River	Filamentous & planktonic algae	Moderate
Massey Mill Pond	35	Leipsic River	None	None
McColleys Pond	49	Murderkill Creek	Planktonic algae	Minimal
McGinnis Pond	31	Murderkill River	filamentous algae	Moderate
Moores Lake	28	St. Jones River	Planktonic algae	Minimal
Silver Lake(Dvr)	158	St. Jones River	planktonic algae	Moderate
Silver Lake(Mil)	29	Mispillion River	none	None
Tubmill Pond	5	Mispillion River	filamentous algae, hydrilla	Moderate to Severe
Wagamons Pond	41	Broadkill River	hydrilla, filamentous algae	Moderate
Waples Pond	50	Primehook Creek	hydrilla, bladderwort	Moderate

aerial survey is used to estimate use of each site by fishers and will be used to track fishing effort over time.

2.7.2.6.2 Commercial and Recreational Trends for the Estuary

The Delaware Bay has more than 200 resident and migrant fish species. The National Marine Fisheries Service compiles fisheries statistics that they receive from state agencies. In 1998, commercial landings recorded in Delaware were 7,898,000 pounds which was 2% of the record set in 1953 of 367,500,000 pounds. Recreational angler trips were measured at 910,000 (Commerce, 1999). In the Delaware Estuary the value of the commercial finfishery was about $1.4 million in 1990. The value of the recreational fishery in the Delaware Bay alone was about $25 million.

Recreational fisheries are economically more important than commercial fisheries because their value to the economy has a higher value. Until the 1960s, the most economically important fishery was commercial menhaden. Today weakfish hold this position partially because of their recreational value. The weakfish stock has shown signs of decline in recent years. Sturgeons, the alewife, and shad have declined substantially since the 19th century. Shad and juvenile stripped bass have shown some improvement. Investments in wastewater treatment infrastructure and harvest restrictions have contributed to improvements. Long-term problems associated with the fisheries include pollution, over fishing, habitat degradation inside and outside the estuary, and natural factors (Sutton, 1996).

2.7.2.6.3 Recreational Fisheries

Due to heavy fishing pressure on the freshwater ponds in the Basin, active fisheries management is necessary to sustain the resource and maintain recreational value. In addition, the rivers of the Delaware drainage receive fishing pressure seasonally. The most sought after resident freshwater gamefish is the largemouth bass (*Micropterus salmoides*). Many fishing tournaments and man-days of fishing are directed strictly toward this species. Catch and release fishing by anglers is a major factor in preserving the quality of this fishery (Martin, 1997). Identifying and protecting spawning habitat is crucial, especially in tidal waters. Due to low recruitment into these fisheries, supplemental stocking of fingerlings is conducted when necessary.

Recreational fishing has steadily increased over the past 10 years. The highest projected catch and effort is typically for the following species: largemouth bass, bluegill (*Lepomis macrochirus*), pumpkinseed (*L. gibbosus*), black crappie (*Pomoxis nigromaculatus*), white perch, yellow perch, chain pickerel (*Esox niger*), and catfish (*Ictalurus sp.*). The size and structure of gamefish populations in state-owned ponds are intensely monitored. The increase in fishing effort has continued, resulting in a need for more public freshwater fishing opportunities. A project to construct new ponds (less than 5 acres in size) on public lands was initiated, with construction funding available beginning in 1998.

2.7.2.6.4 Spawning/Nursery/Rearing/Feeding Habitat

Yellow perch and golden shiners (*Notemigonus crysoleucas*) utilize submerged aquatic vegetation (SAV) for spawning and nursery areas. Other species, especially sunfish, may nest adjacent to SAV, using it as cover and as a nursery area for their offspring. It is critical that these habitats be identified and protected from degradation. Siltation caused by shoreline development and destruction of shoreline buffers is a major destructive factor, killing SAV and smothering egg masses that are within the beds. Dredging and channelization projects only exacerbate the situation in those watersheds. This type of alteration would severely affect shellfish, plant, and fish species by direct take, and by alteration of spawning, nursery and feeding habitat.

Due to impediments that prevent upstream migration, river herring (blueback and alewife) utilize spill pools below ponds for spawning. Large spawning aggregations have been observed below the outfalls of some ponds (Seagraves and others, 1990). The protection of critical spawning habitats is important for the reproductive success of these anadromous species.

Tidal wetlands, which become inundated during high tide conditions, are important feeding areas for predatory fish. This factor should be considered when drafting tidal wetland protection plans. The potential for bulkheading and private piers to impact or destroy the ecological integrity of these areas should also be considered before issuing permits.

In areas with limited cover, dead falls and other natural debris provide protection for prey species. Mass removal of this critical 'habitat' could be detrimental to the populations of such species. Where it is possible, natural debris should be left intact to ensure adequate cover for various fish species.

Water quality conducive to growth, survival and reproduction of aquatic species must be maintained or improved. Runoff of pesticides and herbicides, excess nutrients, toxic chemicals, ditching, dredging, siltation, clearcutting for development, and loss of woodland buffers adversely affect water quality. Depending on the causative factor, aquatic species can be adversely affected during any life stage.

Water quality degradation and subsequent eutrophication have also been linked with Pfiesteria piscicida, a toxic marine microorganism that can cause sudden large fish kills. This organism can persist in the environment in a dormant state, but become active when conditions are conducive to its growth and survival. It appears to thrive in nutrient-rich waters, which derive excess nutrients from various sources including runoff from lawns, golf courses, septic systems, farms, and discharge from wastewater treatment plants (DHSS and DNREC, 1997). The potential for this toxic organism to invade Delaware waters should be taken seriously. Preventive measures and efforts to curb excess nutrients should be undertaken immediately, before the organism becomes a human health risk and/or affects local fish populations.

2.7.2.6.5 Lakes and Ponds

Most public ponds within the Delaware Basin have problems with nuisance aquatic plant growth, which in some cases is so severe that access to the pond for water-related activities is limited or even eliminated (*see Table 2.7-3*). The presence and spread of exotic aquatic vegetation has been documented from 1966 (Lesser, 1966) to the present (Miller, 1988). Exotic vegetation out-competes beneficial native vegetation, clogs waterways, and impedes fishing. Nutrient enrichment and subsequent water quality degradation give exotic vegetation a competitive edge over native vegetation. The types of plants that create the most problems include several species of filamentous algae, and two introduced species of submerged aquatic vegetation: hydrilla (*Hydrilla verticillata*) and cabomba (*Cabomba caroliniana*).

The Division of Fish and Wildlife (F&W) uses aquatic herbicides and an aquatic weed harvester to mitigate these problems in the public ponds. This task is carried out as requested and as resources are available. The control of excess aquatic vegetation can be expensive, costing Delaware an annual average of $40,000-$50,000 (Miller, pers. comm.). For most years, requests for aquatic plant control overwhelm the resources available for F&W to respond. Finally, it has recently been observed that the treatment of hydrilla with herbicides is usually followed by infestations of filamentous algae– an even worse problem. This pattern needs to be further verified, but, until then, herbicide control of hydrilla should be done with extreme caution and only when absolutely necessary.

Filamentous Algae

Extensive floating mats of these algae are observed during the summer months on the surface of ponds throughout the State. At moderate and slight levels of infestation, filamentous algae cause little trouble for people and provide beneficial habitat for aquatic life. In extreme abundance, thick-floating mats of filamentous algae have inhibited and even temporarily eliminated recreational use of some ponds and lakes. Effects of heavy infestations on fish populations are unclear. In a few examples, severe infestation of filamentous algae every year causes residents to complain for much of the summer, yet bass and bluegill fishing remains very good. On the other hand, in the late spring, fish kills involving primarily large bluegills have occurred in these same ponds. Although the causes of these kills have not been positively verified, it usually coincides with the first appearance of floating filamentous algae mats, and has been attributed to a combination of factors, including stress brought on by severe eutrophic conditions.

A handful of species is responsible for filamentous algae infestations in Delaware ponds including Pithophora, Rhizoclonium, Hydrodictyon and Lyngbya. Aquatic herbicides and mechanical harvesting are the control methods of choice. Harvesting is the only viable way to remove Lyngbya mats, and has the added benefit of removing nutrients from the system. All but Lyngbya respond well to herbicides, but there can be detrimental water quality effects caused by the release of nutrients and oxygen-demanding substances from decaying algae. In some treated ponds, a dense bloom of phytoplankton blue-green algae almost always follows herbicide treatment of algae mats. This bloom is characterized by poor water quality, including pH levels rising above 9.5, biological oxygen demand concentrations over 10.0 mg/l (acceptable concentrations are < 5 mg/l) and increased murkiness of water.

Hydrilla and Cabomba

Incidental or deliberate introduction of non-native aquatics can cause major problems to existing native species, fishing, other forms of water-based recreation, and water quality. Although there are numerous examples of exotic species in this drainage, several species have more potential to cause negative impacts.

Hydrilla and cabomba are introduced species of submerged aquatic vegetation (SAV). Although SAV is desirable in moderate-to-high abundance (occupying about 40 to 60 percent of the bottom and water column of a pond), these two species can cover up to 75 to 95 percent of the bottom and water column. Such extensive growth inhibits boating access and fishing effort, and can also upset predator-prey relationships that support normal growth rates and numbers of warmwater gamefish (Swingle, 1950; Cooper and Crowder, 1979; Colle, 1980; Savino and Stein, 1982; Werner and others, 1982).

Hydrilla and cabomba can be controlled using approved types of aquatic herbicides. Lowering the pond water level during the winter and, thereby, freezing the root system can also control cabomba. Hydrilla does not respond well to water-level drawdowns because it produces tubers, which are not as susceptible to freezing. The control of both these plant species must be done very carefully, for there is an apparent pattern of herbicide treatments being followed by even more problematic infestations of filamentous algae and phytoplankton blue-green algae. Despite the access problems caused by hydrilla and cabomba, water quality associated with these and other SAV species is better than that associated with filamentous algae and phytoplankton blue-green algae.

Carp and Gizzard Shad

Common carp (*Cyprinus carpio*), a 19th century introduction to North America from Eurasia, and the native gizzard shad (*Dorosoma cepedianum*) are nongame fish species. When extremely abundant, these species can upset the ecological balance in ponds. In the Delaware Basin, Lake Como, Massey's Millpond, Silver Lake (Dover), and Silver Lake (Milford) all contain carp and gizzard shad in large enough numbers to potentially impact other fish species. There are no ponds in the Basin where gizzard shad are dominant, although the species is abundant in a few ponds. There is no direct evidence that either of these species is a problem, or represent a threat to the gamefish populations.

Grass Carp

One species that is considered an exotic, but is used as a tool for aquatic vegetation control, is the grass carp (*Ctenopharyngodon idella*). In Delaware, only controlled stocking of sterile triploid grass carp is permitted. The State of Maryland is concerned that this herbivorous fish may escape from Delaware ponds into the Chesapeake Bay, where they could potentially destroy beneficial aquatic vegetation. Because of this concern, a moratorium was imposed in October 1995 on the stocking of grass carp in waters that empty directly into Chesapeake tributaries.

Asiatic Clam

The Asiatic clam (*Corbicula fluminea*) is an exotic species that has a widespread distribution in the Delaware Bay drainage, initially being found in the Delaware River near New Castle. It has altered ecosystem food chains, decreased diversity, and out-competed or displaced native mussel species, some of which are rare. Its tolerance of water quality degradation gives the Asiatic clam a competitive edge over more environmentally sensitive native mussel species. Ironically, as a filter feeder, the Asiatic clam may have some beneficial effect on water quality. The significance of any such potential benefit is not known.

Zebra Mussel

The potential for zebra mussel (*Dreissena polymorpha*) invasion exists for some areas in the Delaware drainage. Environmental conditions conducive to zebra mussel survival exist in northern and central Delaware waterways, which have typical water conditions for zebra mussel habitat. Zebra mussel veligers are found in the upper Susquehanna River, a major tributary to Chesapeake Bay, which presumably came from the Hudson River giving the Delaware River just as much chance for invasion via the same source. Zebra mussels can impact water dependent industries by clogging systems and decreasing diversity through competition with native species for food and habitat. Once established, zebra mussel populations prove difficult to control, so preventive measures need to be considered.

2.7.3 CURRENT SOURCES OF IMPACT UPON LIVING RESOURCES

2.7.3.1 Loss of Available Habitat

Baseline data for the original historic habitat in the Delaware Basin are not available. However, we do know that Delaware Basin forest acreage was lowest in the late 19th century, as the demands for pastureland, wood for construction and energy, and farmland reached its zenith. Abandonment of unproductive farms during the Depression, followed by the industrialization and urbanization of the workforce, led to a decline in the number of people working on farms. This phenomenon, coupled with the invention of the automobile and tractor, and the decreased need for wood for fuel, led to an overall increase in total forest acreage in the early 20th century. In many areas of Delaware, the suburban development and economic prosperity, which began in the middle of this century, caused these young forests to be replaced with homes, roads, retail shopping centers, and commercial areas. A series of aerial photographs taken approximately every decade from 1926 until the present provide a glimpse of changes in available habitat in the Basin. The permanent loss of upland habitat, although continuing, has not increased appreciably over the past 70 years, although changes in the quality of these remaining forests is harder to measure.

Assessments of forest cover have been conducted by the United States Department of Agriculture three times over the last 40 years, most recently in 1986. The document, Forest Statistics for Delaware - 1972 and 1986 (Frieswyk and others, 1988), compares the last two forest inventories for each county in Delaware. Although total forest cover over this time decreased by 38,000 acres statewide, this loss was for the mostly related to the urbanization of New Castle County. Sussex County lost an estimated 4,000 acres of forest during this period.

Most losses of wetland habitats in Delaware have also occurred following European settlement. Over the last 300 years, the landscape has gradually become dryer due to the construction of canals, drainage ditches, and stream channelization projects to promote agriculture, shipping, and mosquito control. Dams to build millponds for waterpower altered natural freshwater and tidal fluctuations, creating new anthropogenic habitats that replaced the existing natural ones. Thousands of acres of wetlands were drained throughout the State.

In the 1980s, the Department was concerned about the destruction of unique and significant exceptional wetlands in Delaware. The DNHP located, mapped, and developed community classifications for these wetlands based on the community's assemblage of rare species, geologic origins, and their distinctive physiognomic characteristics (McAvoy and Clancy, 1993). In order to convey the location, distribution, and importance of these exceptional wetlands, they were mapped and identified as Type I wetlands (e.g., bald cypress, Atlantic white cedar, coastal plain ponds).

Although Type I wetlands are considered the most unique and significant/exceptional wetlands, other wetland habitats, designated Type II wetlands, (e.g., riparian mixed hardwood wetland communities, mixed emergent communities, etc.) are also important refugia for many rare and not-so-rare native plant and animal species. An intensive biotic survey of palustrine and terrestrial habitats of Type II wetlands bordering several rivers confirmed the value of such wetlands. According to the DNHP, the riparian habitats associated with some of these rivers include some of the finest and most diverse habitats, and are home to many species of rare plants and rare animals. Wetland habitats not classified as either Type I or Type II are nonetheless also very important to biotic integrity.

2.7.3.2 Fragmentation of Habitat

In addition to the loss of available habitat, the remaining habitat in the Delaware Basin has become increasingly splintered and isolated. Fragmentation of forest was already significant by the beginning of the 19th century, largely due to land clearing for agriculture. Today, most of the remaining forest in the Basin is found along stream bottoms and floodplains that have remained unavailable to agricultural production.

The clearing of the Delaware Basin forest was accomplished nearly 200 years ago and has had several effects. Some non-game animal species, which require extensive mature forests to persist, have become significantly reduced in numbers or extirpated. The remaining fragmented forest habitats contain a high ratio of "edge" as opposed to interior forests. Detrimental edge effects on the forest include increased sunlight, wind exposure, drying of soils, higher temperatures, loss of interior species, and increased vulnerability to exotic species invasion. Fragmentation favors species which prefer an open patchwork of woodlots, edges, and meadows. Examples of such species include red fox, brown-headed cowbird, raccoon (*Procyon lotor*), and whitetail deer. These animals have become more numerous and live closer to humans than they ever have.

As the Basin's human population increases, long-range management considerations become vital as human/pet/wild animal conflicts increase. Already, the increased threat from zoonotic diseases (Lyme disease, hanta virus, and rabies) has caused public health concerns as animal and human populations increasingly interact.

2.7.3.3 Sedimentation

Accumulation of sediment in Delaware Basin streams has had terrible consequences for aquatic systems. Centuries of forest clearing, livestock grazing, and agriculture contributed enormous amounts of soil and gravel to both tidal and non-tidal rivers, creeks and streams. The worst problems occurred before the 1950s. Modern soil conservation practices have greatly reduced the damage. However, there are still problems with sediment entering streams. As a result of this sediment load, fish spawning areas, which require clean sand, are destroyed. Sediment has contributed greatly to the demise of numerous species of mollusks and other filter feeders. Some historic species no longer survive in Delaware. Others have been driven close to extinction in all but the highest quality streams. Many species exist only in the protected portions of the watershed (mainly, small tributaries).

Fortunately, once sediment loads are sufficiently reduced, it is possible to achieve a higher level of stream quality, and, thereby, gradually improve stream habitat over succeeding decades. At that point, refuge populations of currently stressed aquatic species can be reintroduced. Therefore, it is crucial that we save all of the aquatic components possible. Aquatic fauna and flora must be allowed to survive in the remnants of good quality habitat that are left, so they are available for spreading diversity throughout the watershed when better conditions are established.

2.7.3.4 Modern Forestry

The application of silvicultural techniques has improved greatly over the last 100 years. Modern foresters develop forest management plans that effectively deal with a wide variety of conservation issues, including sediment control, game management and hunting, and passive recreational opportunities in addition to providing lumber and fiber products. Each forest management plan is tailored to the request of the landowner. These can range from maximized production of forest products by eliminating competing "non-productive" elements in the forest, to timber stand improvement and forest legacy programs. In Delaware, one result of this planning was the development of loblolly pine plantations in the southern portion of the state. These trees are actively managed by mechanical and chemical means to achieve superior forest products within a projected 40-to-50 year harvest rotation (Brown, per. comm.). This practice has also reduced biological diversity by changing the structural and functional forest diversity. It 'homogenized' the oak-pine forest.

An effort to develop "working forests" that promote biotic diversity while maintaining economic viability of forest products is currently underway (Brown, per. comm.). However, the vast majority of forestland in the State is in private ownership and not under the management of state foresters. The Delaware Department of Agriculture (DDA) Forest Service directly manages less than 10,000 acres of forest. By comparison, forests owned by private forest industry total 30,000 acres. In 1986, the U.S. Forest Service estimated that private individuals owned 88 percent of Delaware's forestland. Much of the timber on these lands is being managed without a forest management plan, essentially as it has been for 300 years. Although the total privately-owned forest habitat does not appear to be decreasing significantly in the Delaware Basin, it typically:

- has trees less than 50 years old;
- is smaller than 100 acres in size;
- does not have a forest management plan;
- is owned by several different people;
- is too wet to clear for farmland;
- may be used as supplemental grazing for livestock;
- has been further fragmented by tax ditches; and
- provides supplemental income to the owner through hunting leases, firewood sale, or through a once in a lifetime timber harvest.

Often, following the private contracted harvest of timber on these private lands, the DDA Forest Service receives complaints from landowners about how badly their forest was treated. A "working forest" management plan could avoid many of these problems if the landowner would contact the Forest Service prior to signing a contract (Brown, pers. comm.).

2.7.3.5 Exotic Species

A major threat to fragmented natural areas in both public and private holdings has been the introduction of numerous invasive exotic or alien species of plants and animals. Unlike most introduced exotic plant species which are benign additions to the landscape, invasive exotic plant species are overrunning forests, wetlands, open habitat, and aquatic communities. Native plant communities are in direct competition with introduced exotics. Exotic species, combined with habitat disturbance/fragmentation and an increasing population of whitetail deer, has placed the remaining natural habitat in the Delaware Basin under an additional threat. At present, fewer exotic species currently threaten the Delaware Basin's natural areas than in Piedmont habitats. But this is likely to change over the next few decades.

Over one-third of the species in Delaware's flora are exotic. Several dozen species have the capability of permanently altering habitat. To date, only the largest, oldest, most intact, or most isolated forest tracts have been able to resist exotic invasion, but even these forests are ultimately vulnerable to shade tolerant exotic species such as Norway maple (*Acer platanoides*). Many sites are in grave need of exotic species control and habitat restoration.

Although the presence of exotic species is well known, very little data (other than "present/absent" designation) have been collected that documents the extent of the exotic infestation in Delaware. Invasive exotic-species' issues have not been a priority with land managers, planners, or heritage databases. Meanwhile, new species of plants are being introduced into natural areas, sometimes intentionally. As the exotic plant species compete with native species for the already reduced available habitat, they do so without the threat of disease or insect herbivores that affect natives. Even deer, which eat almost anything, seem to favor the native plants over the new, unfamiliar, and/or unpalatable imported exotics.

A common event (such as the blowdown of a large tree during a thunderstorm) creates available habitat for exotic invasion, especially by vines (i.e., Asiatic bittersweet (*Celastrus orbiculatus*)). Once established in sunny gaps created by the death of a mature tree, the vines smother the normal successional replacement of the fallen tree by native saplings. Clambering over the young trees, covering them with their leaves, denying them sunlight, the vines maintain an exotic tangle that native species cannot penetrate. These vine thickets are permanent. In the normal successional process, this canopy gap would return to forest eventually. Today, once the exotic vines become established, the forest cannot recover without human intervention. Instead, the vines slowly kill surrounding trees, gradually expanding the gap in an ever-widening circle.

Under these circumstances, a catastrophic storm would create the same scenario, but instantaneously and over a larger area. For decades, in most Piedmont forests, an incredible number of exotic seeds have been raining on the forest floor every year. Seedling vines have sprouted to become a significant understory component. Once an ice storm, nor'easter, tornado, or hurricane strip or kill the forest canopy, these seedling vines will be able to utilize the increased nutrient load released from the dead leaves and branches left by the storm. The combination of the nutrient boost and the increased sunlight from the reduced canopy will allow the vines to permanently alter and dominate entire forests. At this point, the cost of restoration management of these forests would be enormous. An effort to protect the best natural forests must begin in the immediate future, before a catastrophic event. It is only a matter of time until this scenario becomes reality.

Major climatic storm events occur on regular, if not predictable basis. These events are part of the abiotic processes that all plants and animals in the region are subject to. Human alteration of habitat over the past three hundred years has made some parts of the ecosystem more vulnerable and less likely to recover from future storms. Any similar event, whether natural or man-made can potentially open the canopy to promote the spread of exotic plant species, and, thereby, further degrading the remaining forests.

2.7.3.6 Phragmites

Phragmites (*Phragmites australis*) is believed by many to be the most widely distributed angiosperm in the world, ranging all over Europe, Asia, Africa, America and Australia. Phragmites is considered to be native to North America since it is known to have been in New England for at least 3,500 years. It is a tall (up to 14 feet in Delaware), perennial grass that tolerates a wide range of salinity, from fresh to polyhaline.

Phragmites has a very aggressive growth pattern, and in many wetlands in Delaware has shown the ability to displace many plants in brackish and salt marshes and form a dense monotype. Phragmites primarily spreads vegetatively by rhizomes or runners, but it does establish new stands from seeds or rhizome fragments. When Phragmites is interspersed with open water or with other vegetation, it can provide some valuable wildlife habitat by adding to the plant diversity of the area. However, when the plant forms monotypic, impenetrable stands it provides very poor food and cover. Because Phragmites grows in such dense stands and is characterized by a high rate of litter production, it also has an influence on marsh hydrology through its ability to "fill in" the micro-topographic relief of the marsh surface. Small first and second order streams are filled, thereby flattening the marsh plain and interfering with the wetting-drying cycle of the marsh. The loss of marsh creeks adversely impacts fish species that thrive in this interface between the marsh and estuarine waters. Due to the fact that dead Phragmites stems remain standing for several years and do not decompose readily once they come in contact with the marsh surface, this dead material is probably less available to the food chain. While the impacts of Phragmites invasion have not been well quantified, most wetland managers agree that since a Phragmites marsh is structurally very different from the marsh it displaced, its ecological function is probably different as well.

In the last 50 years, there has been a noticeable increase in Phragmites populations along the East Coast. Recent research indicates that the current Phragmites has a different chromosome makeup than our native Phragmites, one that is similar to populations found in Europe. This suggests that the current form was introduced from Europe, or our native population underwent a spontaneous chromosome change in situ. Regardless of how it got to its present form, the Phragmites that is currently dominating Delaware wetlands is playing the part of an exotic invader.

The Delaware Basin currently has scattered, immense monotypic stands of Phragmites seen in the fresh and brackish marshes in all three counties. Where Phragmites first establishes in many wetland systems - artificially elevated areas created by ditch excavation, filled areas such as dikes and levees, natural upland edges adjacent to marshes, and channel and tidal ditch edges which are elevated by the natural deposition of fluvial sediments - all are present within the Basin. These are the areas where Phragmites was first noticed in the marshes that are now essentially monotypic stands of the plant. It appears that once Phragmites establishes a foothold, its aggressive vegetative growth and expansion properties allow it to dominate an area over a period of years. It should be noted that Phragmites grows more robustly in lower salinity areas. Higher salinities areas within the Basin could possibly slow and prevent this process from occurring.

The situation of narrow fringes of Phragmites around the marsh edges and scattered patches within the marsh does not constitute a big problem as far as wildlife habitat is concerned. The problem lies in the potential of these initial stands to spread and eventually form a monotype. Requests from landowners to the Division of Fish & Wildlife's cost-sharing Phragmites control program, revolves around "cosmetic" problems with the plant. Its tall aerial stems growing next to the marsh edge are blocking the aesthetic views to the wetlands, and making access to these areas more difficult. Many landowners are interested in getting rid of their Phragmites so they can get their view back or so they can have easier access to a creek or dock.

One potential benefit of Phragmites that has not been well quantified, especially in natural systems, revolves around its ability as a biological filter. Scientists from Germany, Australia, the United Kingdom, and the United States (Dr. Jack Gallagher at the University of Delaware) have created wetlands of Phragmites for treating point-source pollution. Whether or not the Phragmites in the Inland Bays in its current distribution could help decrease eutrophication problems is a question with not many answers at this time.

2.7.3.7 Mosquitoes

Tiger mosquitoes (*Aedes albopictus*) first appeared in Milford in 1987, probably as a hitchhiker within a load of old tires (Stachecki, 1998). Although a native of the Pacific and southern Asia, a substantial population was detected in the United States in Houston, Texas in 1985. Twenty-five southern states documented tiger mosquito presence by 1995. They are established in Maryland (1987) and New Jersey (1995). Found as far north as Chicago, the 0^{o} C daily mean January isotherm has been used as a conservative estimate of the species' northern limits (Crans, 1995).

Although known as much for their striped abdomen as their aggressive biting, tiger mosquitoes will bite during day or night. They are smaller than saltmarsh mosquitoes (*Aedes sollicitans*), Delaware's worst biting offender, and less mobile. Fortunately they travel no more than 300 yards from breeding places, unlike saltmarsh mosquitoes which can travel up to 40 miles for a blood meal. Tigers are known for displacing native species of mosquito. Yellow Fever Mosquitoes in the southern U.S., formerly known as the ultimate domestic pest, are now less prevalent than the Tiger (Crans, 1995).

Known as the "container" mosquito for its opportunistic container breeding habits, they utilize natural and man-made container habitats. Its ability to breed in as little as 1/4 inch of water makes this mosquito hard to control. They can breed in tires of all sizes, buckets, dishes, and crushed aluminum cans, and even within the holes of a socket-set case (Crans, 1995).

Breeding sites are difficult to locate and spray. Coupled with the species broad range of prey, the disease potential is great. The more aggressive tiger transmits dengue fever, called "bonebreak fever," a common disease of the Caribbean. Yellow fever, another virus with as high as a 30 % death rate in children, is mosquito-spread and has been found in tiger mosquitoes in Puerto Rico and Mexico. Transmission of the more common Eastern Equine Encephalitis (EEE), a bird-borne virus, is possible. EEE is a virus that attacks the meninges (encapsulating tissue) of the brain and spinal cord causing swelling in these tissues. Since 1955, there have been approximately 300 reported human cases of EEE in the eastern U.S. The mortality rate for EEE in humans ranges from 30% to 70%, depending upon an individual's age and level of health. Survivors of EEE often suffer permanent neurologic deficits. The last confirmed EEE human fatality in Delaware occurred in 1985. As a "front line" warning to the presence of EEE within the State, the Mosquito Control Section maintains sentinel flocks of chickens placed throughout the State - much the same as coal miners used canaries to warn of gas leaks. These chickens have direct contact with biting mosquitoes that may be EEE infective. On a bi-weekly schedule, each of 62 chickens is "bled" and the State of Delaware Public Health Laboratory in Smyrna test plasma serum for the presence of the EEE antibody.

Today, mosquito populations are in much better check. The reasons include a more complete knowledge of mosquito biology/natural history, implementation of wetland modifications since 1970 known as Open Marsh Water Management (OMWM) that reduces mosquito breeding habitat, and the use more effective chemical control products in a more efficient and responsible manner.

2.7.3.8 Nutria

Nutria (*Myocaster coypu*) are large, beaver-like, semi-aquatic rodents. They resemble beavers or muskrats but differ by having a long, round tail and webs between the inner four toes of their hind feet, but not the fifth outer toe. Large males may grow to 20 pounds and large females up to 18 pounds, but most adults average 8 pounds. They are capable of 2 litters a year, with up to 9 young per litter, and breed at the age of 4.

Nutria were imported from South America to the U. S. in 1899. During the 1930s, fur farms raised nutrias in at least 7 western and mid-western states. After World War II, nutria fur production became unprofitable. Many animals were released or escaped. Elsewhere, trappers were transplanting nutrias into marshes. State and federal agencies also transplanted nutria. Nutria became established on the Delmarva Peninsula either from fur ranches or transplanting in the 1940s. Like other exotic species, nutria negatively impact the areas where they become established. They are highly profilic, have no natural predators, cause extensive damage to marshes and displace native species. They are capable of killing large tracts of marsh by complete removal of all plant material, called an "eat-out." Like muskrats, nutria dig tunnels, or burrows, in banks. They compete directly with muskrats for food and cover. Nutria are likely to keep expanding their habitat throughout Delaware and the Basin due to the extensive network of ditches.

2.7.3.9 Gypsy Moth

The gypsy moth (*Porthetria dispar*) was accidentally introduced into the United States from Europe in 1869 and has been spreading throughout North America ever since. Since its introduction, this non-indigenous insect pest has defoliated millions of acres of oak hardwood forests in North America. In 1981, over 13 million acres were defoliated by the gypsy moth in the northeastern United States. In North America the gypsy moth does not have the full compliment of natural controls, such as predators, parasites, and diseases, that help control gypsy moth populations in Europe, North Africa, and Asia. Gypsy moths can reach outbreak levels more quickly and frequently than native forest insect defoliators.

Gypsy moth caterpillars eat the leaves of hardwood trees in the spring. High moth population levels can defoliate entire tree stands in a season. Oaks are the preferred food of gypsy moth caterpillars, but this pest's diet includes over 500 plant species. The gypsy moth first arrived in Delaware in the 1960s, but noticeable defoliation did not occur until 1979 when 10 acres were defoliated in Alapocas woods north of the City of Wilmington in northern New Castle County. Defoliating population levels of the gypsy moth reached Delaware's southern border in 1994.

Defoliation by the gypsy moth has been a serious problem in Delaware since the early 1980s due to the large component of oak in the state. As the gypsy moth defoliation-front has moved southward in Delaware, more-and-more requests have been received by the Delaware Department of Agriculture (DDA) each year from the public to: (1) suppress gypsy moth infestations on private lands; (2) protect foliage and minimize tree mortality by preventing defoliation; (3) limit the nuisance factors (frass falling from trees, caterpillars crawling everywhere, and allergies from caterpillar hairs) associated with high density populations of gypsy moth caterpillars; and (4) protect timber resources.

Oak decline and mortality has been associated with the gypsy moth in each outbreak of this pest since the very first outbreaks occurred in New England. In 1995, Delaware experienced its worst gypsy moth defoliation ever-recorded (65,462 acres). Continued close assessment of gypsy moth populations is essential in curtailing large defoliations.

2.7.3.10 Insufficiently Protected Habitat

Protection of land in Delaware has been attempted from three different approaches: private ownership, public ownership, and regulatory protection. Of these approaches, protection via regulatory processes has been the most difficult and least successful. New Castle County protects lands to varying degrees by ordinance for lands comprising steep slopes, floodplains and riparian buffers, water recharge areas, and land identified as Critical Natural Areas. The level of protection that is accomplished by these laws is significant, especially when compared to Kent and Sussex Counties. However, the limited protection for sites not included in the State's Natural Areas Inventory have all contributed to a continuing pattern of fragmentation and degradation of remaining habitat. Upland areas that do not fit into one of the ordinances are particularly vulnerable. Kent County has recently improved their protection efforts, particularly along riparian buffers. Opportunities to improve protection of habitat exist in all three counties, especially regarding upland forest protection.

Delaware's lack of a Freshwater Wetlands Law has contributed to a continuing attrition of wetlands. Ditching has also significantly altered habitat. Fragmentation due to many anthropogenic causes continues at a significant rate.

2.7.3.11 Other

Historic industrial and nonpoint pollution, including heavy metal and pesticide residues, have contributed to the degradation of Delaware Basin habitats, especially aquatic ecosystems. Historic spraying for mosquitoes and gypsy moths has certainly had negative effects upon the insect and avian fauna of Delaware in localized areas. Improved pest management techniques have reduced this impact. In-depth discussions of these issues are contained elsewhere within this document.

2.7.4 POSITIVE INITIATIVES

2.7.4.1 Protection of Habitat

In 1973, the Delaware Nature Education Center, Inc. (now Delaware Nature Society) brought together 25 experts in their respective fields to identify the most important natural areas in Delaware. Led by the project director Norman G. Wilder and principal author Lorraine M. Fleming, the culmination of this effort was the 1978 publication of Delaware's Outstanding Natural Areas and Their Preservation.

The State of Delaware enacted Title 7, Delaware Code, Chapter 73: Natural Areas Preservation System on February 10, 1978. This legislation and the subsequent regulations that were passed provided the State of Delaware, through the Department, the ability to dedicate public and private nature preserves, identify and maintain a statewide Natural Areas Inventory, and establish a Natural Areas Advisory Council to review and make recommendations to the Department Secretary.

The definition of a natural area is an area "of land or water or both land and water, whether in public or private ownership, which either retains or has re-established its natural character (although it need not be undisturbed), or has unusual flora or fauna, or has biotic, geological, scenic or archaeological features of scientific or educational value" (Natural Areas Preservation System, Title 7, Delaware Code, Chapter 73). Natural character refers to the native plant and animal species and associations that occupied Delaware under the influence of Native North Americans at the time of European occupation.

The following are examples of the major programs conducted by the Lands Preservation Office of the Division of Parks and Recreation.

The Natural Areas Inventory

The Natural Areas Inventory has identified 25 natural areas (out of the 67 identified in the State) within, or partially within, the Delaware Basin (see *Map 2.7-1 Living Resources*). A previously digitized GIS layer for the inventory is currently being compared with DNHP element occurrences. The finished maps will form the basis of a Natural Areas Directory, which will be used as a planning document to help protect Delaware's dwindling natural areas. Once the directory is completed and distributed to interested parties, the task will shift toward updating the inventory by identifying and adding qualified new areas previously excluded, and deleting areas recently destroyed. The Natural Areas Advisory Council must vote to amend the inventory before any changes can be made. Updates of the directory will be sent to the recipients of the first edition. It is hoped that the directory will facilitate the protection of some of Delaware's most important natural areas. Currently, protection of natural areas is voluntary, except in New Castle County. There, the owner, prior to the county's acceptance of any development plan, must produce a Critical Natural Areas Report. Even in this case, the ultimate decision on whether to protect a natural area or not is New Castle County's and not the State's.

In selecting a State-recognized natural area, the Office of Nature Preserves, in conjunction with the Natural Areas Advisory Council, evaluates a site based on the following non-prioritized criteria: representativeness; biological rarity; uniqueness; diversity; size; viability; defensibility; research, education, or scenic value; outstanding geological, archaeological, or aquatic features. Sites can be added or deleted from the inventory.

The Natural Areas Inventory was not intended to include every natural area remaining in Delaware. The intent was to include only the areas that were of statewide significance. As a result, many areas that meet the criteria were not included on the inventory. During the 20-plus intervening years since the inventory was established, a tremendous amount of suburban expansion has taken place in Delaware. Lands formerly considered marginal for housing purposes are being developed today. Areas not currently included on the inventory are being reconsidered for inclusion. Among the concerns and priorities of this review is providing adequate upland buffer to wetlands and stream and river corridors, and protecting the larger isolated upland forest patches and rare habitats scattered throughout the region.

New Castle County's Unified Development Code (UDC) provides protection for lands within New Castle County that have been listed on the State's Natural Areas Inventory. The UDC refers to lands on the inventory as "Critical Natural Areas." County planners work closely with the Office of Nature Preserves and private landowners to coordinate protection of these identified natural areas. The UDC also offers varying amounts of protection for steep slopes, riparian buffers, and floodplains.

State Nature Preserves

There are nine dedicated State Nature Preserves totaling 1,167 acres. These locations are depicted on *Map 2.7-1 Living Resources*. Natural Area Protection Plans are being developed to maintain the natural conditions that merited the original dedication of these preserves. Numerous other possible additions to the preserve program exist within the Basin. Nature preserve dedication is the highest legal protection available within the State, requiring the concurrence of the governor and the legislature to remove or 'deactivate' a nature preserve.

State Resource Areas

Lands purchased by local and state government is the latest and perhaps the most important step in providing protection for areas that contain significant habitat. Thousands of acres scattered across the watershed are now owned by public agencies (see *Map 2.7-1 Living Resources*). Significant habitat remains on these properties.

The State of Delaware has acquired land through various programs for recreational benefit and natural resource protection. The State of Delaware enacted Title 7, Delaware Code, Chapter 75: Delaware Land Protection Act on July 13, 1990. Perhaps better known as the "Open Space Program," the initial funding for this program was provided by the sale of bonds. In 1990, the Open Space Program, administered by the Division of Parks and Recreation's Land Preservation Office, continued a systematic approach to land acquisition that had begun with the Governor's Land Acquisition Program established in 1987.

Farmland Preservation

The Department of Agriculture has been leading the effort to preserve farmland by establishing Agricultural Districts, and purchasing Development Rights to critical farmland throughout Delaware. Because many farms contain some natural areas, the purchase of development rights program offers protection for these areas as part of the overall "working farm". Map 2.2-5 Agricultural Preservation Districts show the lands currently cover under this program.

Private Conservation Organizations

Significant habitats within the Delaware Basin have been acquired by two important non-profit organizations; Delaware Wild Lands, Inc., and The Nature Conservancy. Delaware Wild Lands acquired perhaps the most important natural habitat in Delaware, the Great Cypress Swamp, in the 1970s when a major portion of the property was threatened with development. This 10,000-acre property has been responsibly managed by this organization for over twenty years. Within the Delaware Basin, Delaware Wild Lands holds important coastal and near coastal lands in the Port Penn and Augustine area, near the mouth of the Appoquinimink River, the Liston Point/Cedar Swamp area, and around Bennett's Pier in the Milford Neck area.

The Delaware Chapter of The Nature Conservancy has been very active in recent years working with landowners and acquiring significant coastal and near coastal natural sites in the Milford Neck area and cooperating with Delaware Wild Lands near the Bennett's Pier site, a large parcel on the Mahon River near the bay coast. The Nature Conservancy has interior headwater parcels on the Broadkill River near Milton and between Milton and Ellendale off of Rt. 16. Lately, The Nature Conservancy has been proactively identifying "portfolio" sites in the headwaters of the Broadkill, Cedar Creek, and Mispillion River as part of a Delaware Bayshore ecoregional planning effort. This effort includes a major project within the Blackbird Creek corridor for strategic protection and partnering. The bay and ocean area off of Cape Henlopen has been identified regionally as an estuarine conservation area under their ecoregional plan.

Although a significant portion of their protection and education efforts take place in the Piedmont, the Delaware Nature Society operates the Abbott's Mill Nature Center near Milford. This facility provides an invaluable offering of protected natural lands while giving visitors conservation education opportunities. These educational programs are for both adults and children.

2.7.5 TRENDS

An undeniable fact within the Delaware Basin is that the species composition of the remaining natural areas has permanently changed. The 18th century direct habitat conversion of natural areas to agricultural use has altered a functioning natural landscape into a sprinkling of isolated islands and ribbons of natural areas in a sea of agricultural fields. Add to this the introduction of alien species, pollution, excessive sedimentation, altering of natural waterways, etc., and each natural area is further eroded. In addition to species loss from these direct impacts, the theories of island biogeography have shown that, in general, as landscape patches become smaller and more isolated, they can each sustain a diminished number of species over time (Harris, 1984). In sum, direct loss and degradation of habitat, as well as the loss of connectivity between habitats, has resulted in significant loss of species diversity within our natural areas.

A number of bird species are experiencing local, regional, and, for some, global declines. The taxa most affected are those which depend upon pristine, forest-interior habitats, as well as insectivorous species and ground-nesting species (Davis, 1996). There are a number of local and regional factors, in addition to direct habitat loss, which are thought to contribute to their decline. One likely factor is the loss of structural diversity within forests. This loss, in turn, is due in part to over-grazing by whitetail deer and livestock, modern forest management practices, and the desire for "clean" forests in areas directly managed by people. An additional factor is the explosion in feral cat populations. In many areas, these "super hunters" are present at densities far beyond natural predator densities, and are taking a disproportionate toll on songbird populations (Frink, 1996).

With the exception of fish, freshwater macroinvertebrate species and game species, little is known of the current status of animal populations and their distribution in the Delaware Basin. Several other animal groups, including birds, reptiles, amphibians, and some insects (butterflies) have been sporadically sampled throughout the region. Of the animals and plants that are listed by the Delaware Natural Heritage Program (1998) as species of concern, many are found in Delaware Basin habitats. Generally, the more secretive the animal, the less is known about it. Basically, if more habitats can be protected, both in diversity, connectivity, and size, then the greatest number of species of plants and animals will be able to survive in Delaware.

While many native species have been lost, or severely reduced, others are increasing in number. Species increasing in number include raccoons, opossums, American Robins, resident Canada Geese, Rock Doves, and Brown-headed Cowbirds. These are adaptable, "broad-niche" species, which can tolerate or even thrive on living in a human-dominated, suburbanized landscape. While they may represent "wildlife" to many people, their ubiquity is in many ways an indication of just how unbalanced our natural systems are becoming.

2.7.6 INFORMATION NEEDS

In compiling the information for this assessment, one is overwhelmed with how little is known and how little effort has been made to pull together diverse sources of information. Some of the state's most valuable natural lands are located in this Basin. Although the Department and other non-profit organizations may try to protect these natural lands, the scarcity of data and the lack of a coordinated analysis prohibit any comprehensive protective approaches. The following recommendations highlight some of the major data gaps and information needs.

2.7.7 DATA GAPS AND RECOMMENDATIONS

1. Upland forests have been almost eliminated from the majority of the landscape, limited to floodplain borders, or isolated patches in palustrine forest. What remains continues to decline and degrade because of repeated disturbance. Recommendation: A statewide survey is underway to identify remaining upland forests. Further efforts are needed to evaluate the quality of these areas in the Delaware Basin using such factors as biodiversity, size, age, and exotic infestation. Appropriate actions should then follow such as landowner contact, natural area designation for qualifying tracts, legal protection, and/or restoration. "Reference forests" should be established on public or private conservation lands to provide management baselines.

2. Some rare habitat types may be in danger of disappearing completely from the Delaware Basin. Recommendation: A survey of such habitats should be conducted and summarized. Appropriate actions should be taken to protect these areas, including natural area designation for qualifying tracts, landowner contact, legal protection, and/or restoration.

3. Establish guidelines for protection of these resources in each county and municipal Comprehensive Plan. Recommendation: To varying degrees, each Comprehensive Plan has already incorporated some of the ideas put forward in this document. A dedicated effort to improve and enforce the plans must be made in the future to prevent further degradation of natural resources.

4. Identify and educate private forest owners regarding wildlife habitat, biodiversity maintenance, and the establishment of long-range goals to achieve acceptance of multiple-use land management objectives.

5. The majority of our most critical living resources are dependent upon good quality aquatic habitats as well as a natural flooding regime. Recommendation: Promote activities, which eliminate unnaturally high sedimentation and erosion rates, and unnaturally high nutrient inputs. Assess the effect of direct stream irrigation on aquatic and riparian systems.

6. One of the most significant impacts on our environment comes from the direct and indirect effects of new construction in areas more and more peripheral to existing urban areas, schools, and employment centers. Recommendation: When and where construction is needed, encourage infill to existing developed areas rather than development of "green" spaces. Encourage the placement of trails and other recreation amenities away from sensitive natural areas not suitable for recreation. Continue to work with communities to encourage the protection of stream corridors.

7. Resident geese are becoming a nuisance. Their numbers have been increasing annually in the Basin, and are problematic due to their feces and feather residues, eutrophication of the lakes and streams where they reside, and aggression towards some humans. Recommendation: Encourage stream and pond management that incorporates wide buffers of natural vegetation, including stands of woody species when possible.

8. Develop a uniform approach towards the management of aquatic weeds that does not allow for the degradation of our ponds into dead end filamentous algae pools. Recommendation: Examine current management approaches and develop a more effective, broad-based management approach. Educate pond managers and concerned public with the issues regarding the eutrophication problem in ponds. Encourage major private pond owners to incorporate the same strategies.

9. Recognition of the threat of invasive plant and animal species to the Delaware Basin drainage. Recommendation: Discourage planting invasive plants in Delaware. Discourage introduction of invasive animals to Delaware. Encourage the use of native and non-aggressive exotic plant species. Train management personnel to recognize invasive and to develop management strategies. Make this information available to local citizens and to plant nurseries.

10. The lack of fire during the 20th century on the Delaware upland landscape has had a negative effect upon the fire-dependant plant and animal species across the Delaware's habitats. Recommendation: A test scale controlled burn should be conducted on fire-dependant plant communities

to reestablish the link between fire and the natural diversity and adaptability of the extant species in Delaware's modern forests and marshes. This should be done under the lead auspices of the DDA Forestry Service. The tests could be attempted upon DNREC and/or DDA lands.

11. With new data coming in regarding the status of the American eel (*Anguilla rostrata*) population, continually review the American eel management plan to ensure this fishery's viability. Recommendation: Mandatory reporting requirements should be required to determine the status of the fishery.

12. The American shad is an anadromous fish that breeds in Delaware's rivers and streams. The numbers of shad remaining are low compared to historic populations. Recommendation: Implement American shad restoration and protection projects including the construction of fish passage facilities in every available area, development of a hatchery program, and limiting existing harvests to allow for the population to reach sustainable harvest levels.

13. Recreational fisheries need to be protected from water quality and habitat degradation resulting from accelerated development. Recommendation: Maintain or establish "no wake" zones where needed. Boat wakes can cause siltation and wave action detrimental to submerged aquatic vegetation (SAV). The use of non-structural alternatives for erosion control or a combination of rip-rap with natural vegetation should be emphasized where shoreline erosion is a problem for property owners.

14. Freshwater mussel surveys designed to determine distribution, age structure, and density of the populations is on-going. However, there is currently no protection afforded those areas with high quality mussel populations. Recommendation: Once high quality freshwater mussel sites have been identified, they should be afforded protection from habitat degradation.

15. If it has not been initiated already, a plan needs to be developed regarding how to prevent zebra mussels from becoming established in Delaware (educating anglers, boaters, etc.). Veligers have been found in the upper Susquehanna and it is probably a matter of time before they arrive closer to Delaware.

16. Facilitate the Department's Conservation Reserve Program and the Conservation Reserve Enhancement Program efforts to provide matching funding to landowners to restore habitat.

17. Incorporate Delaware Natural Heritage Program databases with other planning databases, including those in Maryland, so that rare species are identified prior to development.

18. Identify restoration possibilities to increase connectivity between available habitats, including valuable headwater areas.

19. Little information is known about the status of many native fishes (mostly non-game species). More data need to be collected on the presence and population levels of these native species.

20. Phragmites control should not be viewed as eradication, since that is impossible given the nature of the plant and today's control techniques. Much of the fringe Phragmites around the marshes is tucked under trees where the spray from the helicopter cannot reach, or where unacceptable damage to the trees would occur from the herbicide. Developed areas present special problems related to possible non-target damage due to drift, and difficulty in flying around buildings and other man-made structures. These Phragmites populations have the potential to spread and should be monitored through the years to see if natural conditions keep them in check. Practical experience has shown it is much easier to keep Phragmites in a limited area than to rehabilitate that area once it is solid Phragmites.

21. Continue to aggressively monitor and assess both migratory shorebird and horseshoe crab populations and interaction. Put in place restrictions as necessary to ensure the viability of the Delaware Bay as an essential stopover.

22. Protection of rookery sites within the basin should be a high priority. Periodic surveys should be continued to monitor existing colonies and seek new ones. All efforts should be made to limit human disturbance of established colonies.

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2.8 RECREATION

2.8.1 NATURAL RESOURCE BASED RECREATION

The natural resources of the Delaware Bay and Estuary Basin provide opportunities for a variety of recreational activities. From fishing to camping to hunting to hiking, the forests, marshes and open waters of the Basin are popular places for recreation. Within the Basin there are 73,841 acres of land protected by state, federal or private conservation ownership. *Table 2.8.1* shows the breakdown of protected land by management entity.

TABLE 2.8-1 PROTECTED OPEN SPACE

State-Managed Lands	Acres
State Fish & Wildlife Areas	33,024
State Parks	3,873
State Forests	1,155
Privately Managed Lands	
Delaware Wildlands	7,879
The Nature Conservancy	3,115
Federally Managed Lands	
National Wildlife Refuges	24,795

Source: Department of Natural Resources and Environmental Control, 2001

Within the Basin, there are four state parks, two national wildlife refuges, approximately twelve state wildlife areas, and numerous fishing access areas that provide a variety of opportunities for recreation (*see Map 2.8-1 Conservation and Recreation Sites*).

2.8.1.2 Fishing

TIDAL WATERS

Recreational fishing in the Delaware Bay and its tributaries is a popular activity. In the Delaware Estuary, some of the commonly sought-after recreational fisheries include: striped bass, bluefish, carp, catfish, drum fish, summer flounder, white perch and yellow perch. Bluefish and summer flounder are the two most sought-after species in the Estuary (Dove and Nyman, 1995). It is recommended that before fishing individuals should contact the Division of Fish and Wildlife for the most up-to-date information regarding fishing advisories for the Delaware Bay and Estuary.

The Department provides fishing and boating access to tidal waters at twelve locations in the Basin. *Table 2.8-2* shows these locations.

Table 2.8-2 Division of Fish and Wildlife Tidal Water Access Areas

CONTENTS

RECREATION

NON-TIDAL WATERS

The Department provides public access to several ponds in the Delaware Bay and Estuary Basin for the purpose of fishing and boating. *Table 2.8-3* lists these areas.

In order to fish in non-tidal waters, a Delaware fishing license is required. Fishing license sales are an indication of the popularity of the sport. Between 1994 and 1998, Delaware saw a nearly 10 percent decline in the number of fishing licenses sold. This downward trend is consistent with nationwide

Table 2.8-2 Division of Fish and Wildlife Tidal Water Access

Area/Location	# of Ramps	# of Piers
Augustine Beach/Delaware River	2	1
Bowers Beach/Delaware Bay	5	None
Canal Wildlife Area/C & D Canal	None	4
Cedar Creek/Delaware Bay	8	None
Collins Beach/Delaware Bay	3	1
Lewes/Delaware Bay	3	None
Milton/Broadkill River	1	2
Port Mahon/Delaware Bay	3	1
Scotten Landing/St. Jones River	1	1
Woodland Beach/Delaware Bay	1	1
Odessa/Appoquinimink Creek	1	None
Fort Dupont	3	None

trends and is attributed to a variety of reasons, including less leisure time. (Herman, 2001)

The Division of Parks and Recreation conducted a telephone survey of 1,800 Delaware residents between April and June of 2002 for the 2003-2008 Statewide Comprehensive Outdoor Recreation Plan (SCORP). Residents were asked a broad range of questions including ones to gage outdoor recreation preferences, patterns in individual and family outdoor recreation activities, and some environmental perceptions. Of those surveyed for the 2003-2008 SCORP, 92.2% in the Delaware Bay and Estuary Basin stated that outdoor recreation has some importance to them personally and 65.7% stated that outdoor recreation is “very important” to them. When asked if more fishing piers should be a priority for state and local funding, a third of those surveyed that live within the Basin indicated that fishing piers are a “very important” priority.

Table 2.8-3 DNREC Non-Tidal Water Access Areas

Area/Location	Acres	Boat Ramp	Bank Fishing
Division of Fish & Wildlife			
Abbotts Pond	17	Yes	Yes
Andrews Lake	19	Yes	Limited
Blairs Pond	29	Yes	Yes
Coursey Pond	58	Yes	Yes
Derby Pond	15	Yes	Yes
Garrisons Lake	86	Yes	Yes
Griffith Lake	32	Yes	Yes
Haven Lake	82	Yes	Limited
Logan Lane Pond	2	No	Handicapped
McGinnis Pond	31	Yes	Yes
Moores Lake	27	Yes	Yes
Silver Lake (Milford)	29	No	Limited
Tubmill Pond	5	Yes	Yes
Waples Pond	51	Unimproved	Limited
Wagamons Pond	41	Yes	Yes
Masseys Mill Pond	41	Unimproved	Limited
Division of Parks and Recreation			
Killens Pond	75	Unimproved	Yes
Lums Pond	189	Yes	Yes

Source: Department of Natural Resources and Environmental Control, 2001

2.8.1.3 Boating

The Delaware Division of Fish and Wildlife is responsible for overseeing recreational boating, including boat registration, boating safety courses, marine patrols, and public boating access. Between 1996 and 2000, there was a steady rise in the number of boat licenses issued, indicating a continued strong interest in recreational boating. *Figure 2.8-1* shows the number of boat licenses issues for each of these years.

In 1995, the Division of Fish and Wildlife contracted with the University of Delaware to conduct a survey of Delaware-registered boaters. The report, *1995 Delaware Recreational Boating Survey: An Analysis of Delaware-Registered Boaters* provides a comprehensive look at boaters, usage, and economic impacts.

Delaware Bay was second in popularity to Delaware’s Inland Bays. Forty-three percent of the respondents reported that they boated in the Delaware Bay, as opposed to 52 percent in the Inland Bays. Fishing and pleasure-boating were reported as the most popular boating activities (78 percent and 62 percent respectively). Fifty-five percent of boaters surveyed indicated that an inadequate number of public access sites exist. Forty-six percent felt that additional access ramps were needed in Sussex County on the Delaware Bay and Atlantic Ocean. Forty-three percent felt that additional ramps were needed in New Castle County along the Delaware River and Bay (Falk, 1996).

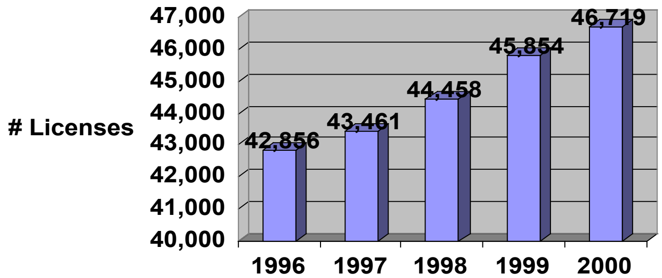
Ramps maintained by the Division of Fish and Wildlife are free for boats registered in Delaware. Boats registered out of State must pay an annual fee for use of the facilities. Ramps on state parks can be accessed for an entrance fee.

Nearly 60% of those surveyed for the 2003-2008 SCORP living in the Delaware Bay and Estuary Basin responded that boating access has some importance for state and local funding.

2.8.1.4 Swimming

Swimming at the beach is a popular outdoor recreation activity among Delaware residents. Statewide, 74.7% of those

FIGURE 2.8-1 NUMBER OF BOAT LICENSES SOLD



surveyed for the 2003-2008 SCORP indicated that they or a member of their household will enjoy Delaware beaches at least once over the next 12 months and 83.1% responded this way in Eastern Sussex County. In fact, in eastern Sussex County, only walking/jogging was more popular among the 28 activities specifically asked in the telephone survey.

In recent years, swimming safety (risk related to pollution) has also become a concern. This is due more to an increase in public awareness than to any trends relating to water quality. Since inception of the Clean Water Act in the early 1970s, our natural waterways are cleaner than they have been in perhaps fifty-plus years.

Rainfall may raise bacteria levels in natural waterways due to runoff from the land. Pollution may also be introduced from point sources, concentrations of wild or domestic animals, or from other sources. These factors may influence the health risk associated with swimming.

Delaware's swimming beaches have been sampled since 1979. As part of an ongoing commitment to provide assurances for the State's residents and visitors regarding swimming water quality, Delaware implemented a revised, formalized Recreational Water Program in 1989. It is one of the most comprehensive programs of its kind in the U.S. Approximately 50 miles of coastline, from Slaughter Beach, Delaware, south to the Maryland state line, are sampled for bacteria, monitored for rainfall, and observed for other factors known to impact water quality. These criteria are a measure of possible human health effects associated with swimming, including gastroenteritis, and infections of the ears, eyes, nose, and throat. Occasionally, swimming-related illnesses may be more serious. Swimming is never a zero-risk activity, even in so-called "pristine" waters.

Delaware's swimming (primary-contact) standards are based on Delaware's declared acceptable risk of 12.5 illnesses per 1,000 swimmers. Studies suggest that the actual risk is in the range of 0.677 illnesses per 1,000 swimmers. Continuous notification to the general public regarding the advisory status of swimming areas is also maintained via a toll-free number.

2.8.1.5 Shellfish

The Delaware Bay supports no recreational oyster harvest. Hard clams are recreationally harvested in the Delaware Bay south of the fishing pier in Cape Henlopen State Park. Hard clams harvests may also occur in other locations in the lower bay in areas which are not closed for public health reasons, but limited data exist to document locations and harvest amounts. Soft clams, surf clams, and razor clams may also be harvested in the Delaware Bay, either recreationally or commercially.

2.8.1.6 Trail

Hiking and bicycling are activities that continue to grow in popularity. Trails and pathways are a growing part of Delaware's outdoor recreation infrastructure. Over the past ten years, the public has recognized a need to develop and expand trails and pathways to use for fitness, recreation, nature exploration and alternative transportation. In the 2003-2008 SCORP telephone survey, physical fitness, in every region of the state, is the number one reason given for participation in outdoor recreation.

The Division of Parks and Recreation compiled public input and developed a list of outdoor recreation priority needs for the 2003-2008 SCORP. Both statewide and in the Delaware Bay and Estuary Basin, walking paths and bike paths rank one and two for the most needed outdoor recreation facilities. The demand for trails and pathways remains high as walking, jogging and biking continue to be among the most popular outdoor recreation activities. Nearly 60% of those surveyed within the Basin indicated that funding bike and pedestrian pathways should be a very important priority for state and local policy makers. Trails in Delaware's state parks, wildlife areas, and other public areas, help to meet this need. Some public sites with trails include Lums Pond, Killens Pond and Fort DuPont State Parks, the Chesapeake and Delaware Canal Wildlife Area, Prime Hook National Wildlife Area and The Nature Conservancy's Edward McCabe Preserve.

While these trails help to meet the needs of the Basin's residents and visitors, additional investments in trails are needed to fulfill pedestrian and bicycle recreation and travel needs. The single most talked about topic at the 14 public workshops held around the state for the development of the 2003-2008 SCORP, was the safety concern for pedestrians and bicyclists. Aside from being too far from the nearest park, Delaware residents indicated in the telephone survey that they do not walk or bike to the nearest park because of unsafe conditions. Given the fact that physical fitness is the most stated reason why people visit a park, 78.8% of those surveyed within the Basin drive their car to their most visited park.

The Division of Parks and Recreation works closely with local governments and state agencies to establish trails for recreation and alternative transportation. The Division grants $750,000 annually to local governments for the protection of greenway corridors and the development of trails through the Delaware Land and Water Conservation Trust Fund.

2.8.1.7 Camping

Camping is a popular activity in the southern portion of the Delaware Bay and Estuary. Several private campgrounds and two public campgrounds at Lums Pond and Killens State Parks provide a variety of camping experiences to Delawareans and visitors. While data are not available on the use of private campgrounds, the Division of Parks and Recreation maintains data on attendance at its campgrounds. During 2003, the public campgrounds at Killens Pond and Lums Pond State Parks received more than 20,000 visitors.

Killens Pond State Park has 59 campsites with electric and water hook-ups, 17 primitive campsites, ten cabins, and a cottage overlooking the pond. Lums Pond State Park has 68 campsites available with no utility hookups and two Yurts, which are round stationary structures with canvas walls.

In 1995, the Division of Parks and Recreation conducted a survey of state park campers. Most of the campers surveyed in Killens Pond and Lums Pond State Parks came from Delaware (58.3 percent, and 42.9 percent, respectively). At Killens Pond, 13.9 percent of campers surveyed were from Maryland, and 10.6 from Pennsylvania. At Lums Pond, 21.4 percent surveyed were from Pennsylvania, and 9.5 percent from Maryland. Most of the remaining campers at these parks were from New Jersey and New York. Of the Delaware campers at Killens Pond, most were from Kent County (53.4 percent). At Lums Pond, most of the Delaware campers were from New Castle County (88.9 percent). The results of this survey indicate that camping in the Basin comes primarily from residents near the campgrounds (Delaware Division of Parks and Recreation, 1995).

2.8.1.8 Wildlife Watching

Wildlife watching is a popular activity, and opportunities for wildlife viewing abound within the Delaware Bay and Estuary Basin. Probably the most popular place for wildlife watching, particularly bird watching, in the Basin and in Delaware is Bombay Hook National Wildlife Refuge. Between October 1, 1999 and September 30, 2000, Bombay Hook National Wildlife Refuge received 169,929 visitors; most came to observe wildlife.

State wildlife areas and state parks along the Delaware Bay coast also afford visitors opportunities to experience a variety of birds and other wildlife.

2.8.2 COMMUNITY-BASED RECREATION

An important part of any recreation picture is the community-based recreation – ballfields, playgrounds and other areas that serve the needs of the immediate community. In the Delaware Bay and Estuary Basin, the community-based recreation needs are generally met at the county and municipal levels.

Within the Delaware Bay & Estuary Basin, there are about 180 acres of municipal parkland and 725 acres of county open space and parkland, providing playgrounds, picnic areas, ball fields, passive recreation areas, and other recreational amenities to residents. While these parks and their amenities provide opportunities for residents to enjoy the outdoors, not all of the Basin's community recreation needs are well met. *Table 2.8-4* lists the municipal parks in the Basin.

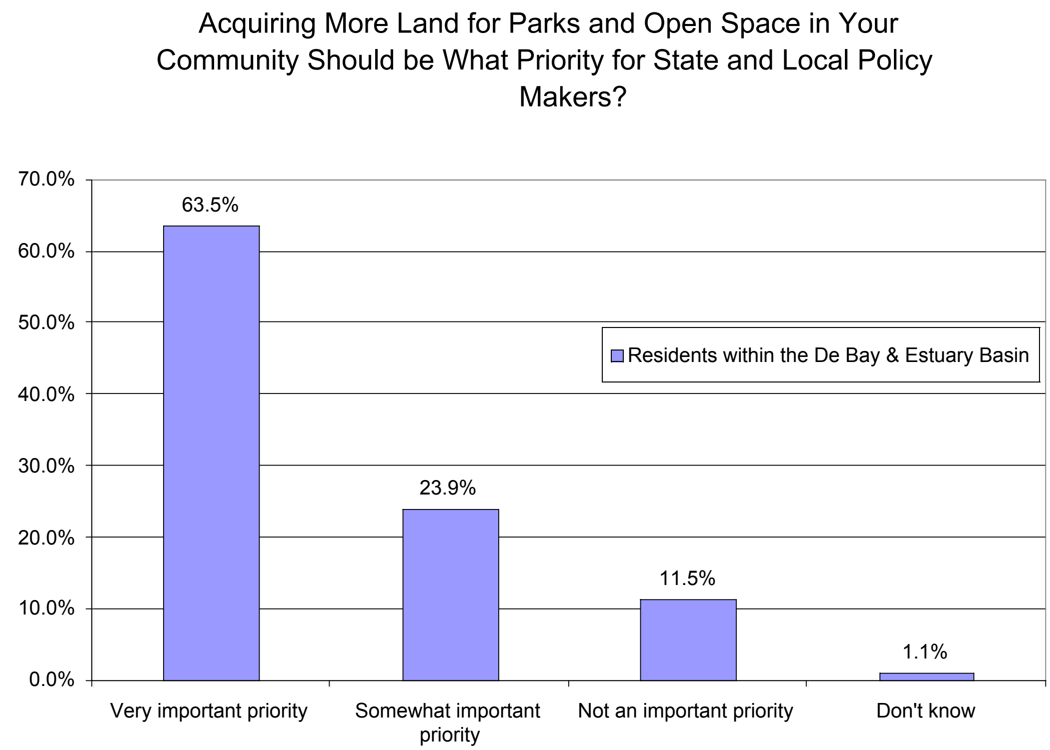
As previously mentioned, the Division of Parks and Recreation compiled outdoor recreation participation patterns and concerns to develop a priority list of outdoor recreation facility needs for the 2003-2008 SCORP. These high prior-

TABLE 2.8-4 COUNTY & MUNICIPAL OPEN SPACE

County	Acres of Parks and Open Space
New Castle County	583
Kent County	278
Sussex County	0
Municipality	Acres of Parkland
Delaware City	10
Dover	260
Lewes	33
Milford	38
New Castle	54
Delaware City Park District	7
Bowers Beach	2
Clayton	.25
Ellendale	1
Georgetown	.4
Harrington	
Kenton	4
Leipsic	2
Little Creek	2
Middletown	85
Milton	4
Odessa	5
Smyrna	97
Wyoming	4
Trustees of NC Common	1
Total Municipal	180

ity facilities are consistent throughout the state including walking and bike paths, picnic areas, playgrounds, hiking trails and swimming pools. When asked about program priorities for the 2003-2008 SCORP, statewide, over 90% responded that the following outdoor recreation programs are very or somewhat important funding priorities. These top priorities are outdoor recreation programs for persons with disabilities and teens, nature education programs and historical education.

FIGURE 2.8-2 PRIORITY FOR ACQUIRING MORE LAND



School playgrounds help to meet some of the recreation needs of the Delaware Bays and Estuary Basin residents. However, across the State, school playgrounds tend to be in disrepair. Equipment is not up to date, or well maintained. These playgrounds often contain safety hazards. Efforts need to be taken to properly maintain equipment and replace equipment as it becomes antiquated.

Availability of parkland and recreation facilities varies throughout the Basin. Traditionally, New Castle County has provided parks and recreation programs for its residents and requires that open space be set aside when land is developed. Kent County manages two county parks in the Basin and requires that open space be set aside by developers when land is developed. Sussex County, however, provides no parks or open space and currently has no open space requirements for subdivisions. Within the Basin, areas further south tend to have fewer county and municipal parks available to them, and the overall need for recreation is greater. Although Sussex County currently does not provide any parks or open space, their 2003 Comprehensive Land Use Plan recommends that the County adopt open space requirements for subdivisions.

Additionally, some areas within the Delaware Bay and Estuary Basin are growing rapidly. As these areas develop, planning and providing the appropriate recreational facilities will be an important part of a high quality of life in the Basin. In fact, residents living within the Delaware Bay and Estuary feel acquiring more land is an important priority for policy makers (refer to *Figure 2.8.2*).

The Division of Parks and Recreation offers matching grants to local governments through the Delaware Land and Water Conservation Trust Fund for park and greenway acquisition and development. Grants from the Trust Fund can help to meet the needs of the Basin's residents.

2.8.3 COASTAL HERITAGE GREENWAY

The Coastal Heritage Greenway ties together the natural, historic and cultural resources of Delaware's coast. Stretching 120 miles from Fox Point State Park north of Wilmington, to the Maryland border at Fenwick Island, the Coastal Heritage Greenway encompasses the entire coastline in the Delaware Bay and Estuary Basin.

To date, protection of resources along the Coastal Heritage Greenway has occurred without a strong coordinated effort. As areas along the coast come under greater development pressure, a more coordinated effort is needed to preserve the resources that give Delaware's coast its character. Through the Coastal Heritage Greenway, coordinated efforts have taken place to interpret Delaware's coastal resources. In 2000, the Coastal Heritage Greenway received national designation as a Millennium Legacy Trail. Additional efforts are needed to protect the coastal resources of Delaware and to keep their natural, historical and recreational significance in tact.

2.8.4 SCENIC ROUTE 9

A steering committee headed up by Delaware Greenways, has been actively pursuing the nomination of Delaware State Route 9 as a Scenic and Historic Highway; an honorary designation. It brings special attention to a roadway's qualities. The main goal of the program is to bring the community together and focus on what can be done to preserve and enhance the corridor. The steering committee is comprised of a wide variety of interested parties, Federal, State & Local governmental agencies, local citizens, and other nongovernmental organizations. The nomination application is being drafted and is based on the outcome of numerous presentations and workshops of the various qualities of Scenic Route 9. The nomination will go forward emphasizing the Natural and Historic qualities of this unique byway. A nomination package is expected to be submitted in early 2004 to DelDOT for their consideration.

2.8.5 DATA GAPS AND RECOMMENDATIONS

1. Require buffers in urban and agricultural areas to provide habitat, improve the aquatic environment and filter runoff.

2. Residents in Sussex County are underserved in recreation. Increase Sussex County recreational program infrastructure.

3. Designate the Coastal Heritage Greenway as a State Scenic and Historic Highway, and develop a corridor plan to protect and interpret the resources along Delaware's coast.

2.8.6 REFERENCES

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ISSUES AND ASSOCIATED RECOMMENDATIONS

This chapter is a condensed summary of the major issues and recommendations that should be considered for implementation in the Delaware Bay and Estuary Basin. They have been organized into three main categories: Nutrient Management, Sensitive Resources, and Non-Nutrient Contaminants. Within these main categories, specific issues have been grouped into high, medium, and low priority concerns. For each of these concerns there in a brief discussion of the issue followed by the Delaware Bay and Estuary team's related recommendations. The recommendations have been slotted into two groups: Type I – Those over which DNREC has direct control, and Type II – Those beyond DNREC's jurisdiction. This chapter's structure allows the reader to identify the Delaware Bay and Estuary Basin's most pressing issues, understand them better, and see what can been done to start addressing them.

CONTENTS

ISSUES AND ASSOCIATED RECOMMENDATIONS

3.1 NUTRIENT MANAGEMENT ISSUES

According to the 2002 (305(b)) Watershed Assessment Report, nutrients pose a serious threat to water quality, aquatic life, and human health. The enrichment of lakes, ponds, bays, and estuaries by nitrogen and phosphorus from surface runoff and ground-water discharge is known to be a contributing factor to eutrophication. Agricultural runoff, urban runoff, and municipal and industrial point source discharges are the primary sources of nutrients. In many watersheds of the Delaware Bay and Estuary Basin, agriculture is the major land use. Poultry production is a major industry in Delaware. Intense animal livestock production tends to create an imbalance of nutrient input to export resulting in accumulation of nutrients that lead to leaching, erosion, and runoff of excess nutrients to ground and surface waters.

Nitrogen can be transported from organic waste-amended soils into ground waters by leaching and to surface waters by erosion or runoff. Nitrate leaching is a major concern in humid regions with excessively well-drained soils that overlay shallow water tables. These conditions are common throughout Delaware. If nitrate enters ground-water supplies, two major environmental problems can occur. The consumption by humans or animals or drinking water with high nitrate levels has been associated with several health problems, the most serious being methemoglobinemia (O2 deficiency in blood) in infants. Additionally, ground waters with high nitrate levels that discharge into sensitive surface waters can contribute to the long-term eutrophication of these water bodies. Erosion and surface runoff can transport soluble inorganic nitrogen and organic nitrogen to surface water. Most of the nitrogen lost in this manner is sediment-bound organic nitrogen. Although the solubility of nitrate favors its loss in runoff as opposed to sediment transport, total nitrogen losses from most watershed studies are usually several fold greater than soluble nitrogen.

In the Delaware Bay and Estuary Basin, phosphorus is the major nutrient that is most frequently found to limit plant growth in freshwater streams. Phosphorus contributes to eutrophication by its movement into surface waters through erosion, runoff, and subsurface flow in artificial drainage and groundwater discharge. Accumulation of soil phosphorus to excessive levels must be minimized to reduce the transport of soluble or sediment-bound phosphorus to sensitive water bodies. Because crop production systems are forced to continually use manure as fertilizer, due to the lack of economically viable alternatives for manure disposal, the systems almost always build soil phosphorus levels well beyond the ranges considered optimum for most agronomic crops. The unfavorable N:P ratio in most manures also results in over-application of manure phosphorus relative to crop needs; to meet crop needs for nitrogen, phosphorus must be over-applied.

3.1.1 TOTAL MAXIMUM DAILY LOADS AND POLLUTION CONTROL STRATEGIES

A Total Maximum Daily Load (TMDL) sets a limit on the amount of a pollutant that can be discharged into a waterbody and still protect water quality. Many of the rivers, streams and ponds that discharge to the Delaware Bay and Estuary have been identified as waterbodies with water quality concerns. As such, they were targeted for TMDL development by December 2006. However, the Appoquinimink and Murderkill Rivers were targeted for earlier TMDL establishment, 1998 (and 2003) and 2001 respectively. The major environmental problems in these waters are nutrient over enrichment and low dissolved oxygen levels. These problems are caused by both point and non-point sources of pollution.

By Secretary's Order, the Department of Natural Resources and Environmental Control has adopted the TMDL Regulations for nitrogen, phosphorous and CBOD5 for the Murderkill and Appoquinimink Rivers. Nonpoint sources of nitrogen and phosphorus are to be reduced by 60% in the Appoquinimink River. Nonpoint reductions in the Murderkill River are required at the following levels, 30% for nitrogen and 50% for phosphorus.

The next step is the development and implementation of Pollution Control Strategies to achieve these TMDLs. Pollution Control Strategies for nutrient management can vary from point discharge elimination to Best Management Practices (BMPs) for agriculture. The remainder of this section details the Delaware Bay and Estuary Basin Team's recommendations that could be used as part of the overall Pollution Control Strategies for the Basin.

3.1.1.1 Riparian Areas

The land immediately adjacent to streams, rivers, or other waterbodies is referred to as the riparian corridor. These riparian areas are very important for enhancing both ecological and water quality values because they maintain unbroken wildlife corridors to the floodplain area, and reduce sediment and nutrient loading downstream. Riparian areas can act as effective nutrient and sediment buffers for their streams, by improving the quality of water moving through these areas. Most of the water entering the streams in the Basin initially passes through these riparian buffers. Therefore, protecting these riparian areas can aid in safeguarding the ecological integrity of the larger downstream floodplain systems.

Recommendations – Riparian Areas
High Priority – Riparian Areas:Type I

Develop Best Management Practices and an accompanying manual that promotes riparian buffers to help trap nutrients and improve water quality in both channelized and natural streams.

Type II

Promote the establishment of forested wetlands and upland forest to supplement and/or restore natural riparian buffers.

3.1.1.2 Channelization

Approximately 2000 miles of tax ditches have been reconstructed in Delaware since 1951. In general, many of these drainage ditch systems involved channelizing the headwaters of existing natural streams, then constructing ditches out and back from headwater channelization. In past decades, natural streams and wetlands were a lower priority than arable land for farming and development. In addition, water quality impacts and possible habitat losses associated with the "way" drainage ditches were constructed or maintained were not really considered. Drainage systems were constructed as efficiently as possible.

Drainage construction and maintenance efforts do impact water quality and wildlife habitat. Research indicates that drainage systems play an important role in the release and transport of nutrients and bacteria. They also disrupt habitat. In many areas, natural riparian vegetation is removed, affecting upland and transitional habitat for many animal and bird species. Lack of canopy affects in-stream temperature and dissolved oxygen parameters, which in turn disrupts biological integrity and diversity.

In light of accumulated information, the state's drainage program has developed and is implementing a number of management practices to address these concerns. A need has been expressed to review these existing practices, define a process that allows consistent use, and track implementation.

The Conservation Reserve Enhancement Program (CREP) is providing increased incentives for landowners to implement certain Best Management Practices (BMPs) to improve water quality and enhance wildlife habitat. CREP is focusing efforts on implementing riparian buffers, grass filter strips, increase wildlife habitat acres, and restore wetlands in targeted water quality and wildlife habitat degraded areas. It is expected that implementation of this program will advance Delaware's goal of meeting water quality standards.

Recommendations - Channelization
High Priority - Channelization:

Type I

Implement the channelization BMP manual that promotes riparian buffers to help trap nutrients and excessive overland runoff. Alternative maintenance techniques should be considered, including: saving trees, mowing along one side of ditch, use of herbicides for those landowners who refuse to establish woody vegetation, or not mowing at all.

Promote ways (utilizing brochures) for landowners affected by ditching to easily obtain monies from Conservation Districts for ditch improvement projects and riparian buffers.

Educate the agricultural community and other people affected by ditching that drainage and wetlands habitat can coexist if managed properly.

Require the use of existing and new BMPs for channel construction activities.

Finalize products of the Department's Comprehensive Tax Ditch Committee.

3.1.1.3 Pond Management

Many of the ponds and lakes within the Delaware Bay and Estuary Basin can be classified as eutrophic due to heavy infestations of algae and aquatic weeds. Although the natural aging process tends to fill a pond in over time, the rate has been greatly accelerated by land use practices adjacent to and upstream from the ponds. Development, farmland runoff, storm events, and heavy use of fertilizers have served to increase the nutrient and silt loads to high levels. This has resulted in excess growth of aquatic weeds and algae, which can impede water-based recreation, adversely affect fish populations, degrade adjacent streams, and cause displeasing odors.

The present 'solution' of weed harvesting and herbicide application is similar to mowing the lawn. While they serve as a temporary solution, the nutrients are still available in the substrate and the water column in excess levels. Concurrently, nutrient inputs continue to be high. A long-term solution relies in responsible management of the lands surrounding and affecting these water bodies. Private and public landowners who reside on or manage these lands need to alter land use practices to reduce nutrient inputs.

Recommendations – Pond Management

High Priority - Pond Management:

Type I

Recommend that the Department develop BMPs for pond maintenance and remediation.

Examine current Pond management approaches and develop a more effective, broad-based management approach. Educate pond managers and concerned public to the problems confronting the eutrophication problem in ponds.

3.1.1.4 Department Policy and Future Direction

A reduction in the amount of nitrogen and phosphorous reaching the waterbodies of the Delaware Bay and Estuary Basin is necessary to reverse the undesirable effects. These nutrients enter the waterbodies from several sources including point sources, nonpoint sources, and from the atmosphere. Point sources of nutrients are end-of-pipe discharges coming from municipal and industrial wastewater treatment plants and other industrial uses. Nonpoint sources of nutrients include runoff from agricultural and urban areas, seepage from septic drainfields, and ground water discharges. Atmospheric deposition comes from both local and regional sources, such as motor vehicle exhaust and emissions from power plants burning fossil fuel.

In January 1998, the Environmental Protection Agency adopted nutrient Total Maximum Daily Loads (TMDLs) for the tidal portions of the Appoquinimink River. These regulations call for 20 percent reduction in phosphorous loads from nonpoint sources. Limits were also established for the Water Farm #1, a spray irrigation wastewater treatment facility serving southern New Castle County. On December 15, 2003 the EPA adopted the Appoquinimink River Total Maximum Daily Load (TMDL) regulation to establish nutrient load limits for the nontidal portions of the River by the end of 2002. The TMDL calls for a 60% reduction in land-based, non-point source contributions to the Appoquinimink River.

On December 31, 2001, the Department promulgated nutrient TMDLs for the Murderkill River and its tributaries. These regulations call for 30 percent reduction in nitrogen and 50 percent reduction in phosphorus loads from nonpoint sources. They also set limits for the Kent County and Harrington Wastewater Treatment Plants as well as some smaller point sources in the watershed.

The attainment of TMDLs for the Appoquinimink and Murderkill watersheds within the State will be achieved through development and implementation of a Pollution Control Strategy (PCSs). The PCSs will be developed by DNREC in concert with the Department's ongoing Whole Basin Management Program, Tributary Action Teams, and the affected public. Tributary Action Teams have been established in both the Appoquinimink and Murderkill watersheds. These Teams are using a process called "Public Talk –Real Choices" in order to develop their PCS. The process calls for learning about the topic, framing the issue in ways that their friends and neighbors can understand, holding public forums to generate principles on which to base the PCS, and generating a PCS to recommend to the Department. The Department will then promulgate the PCS as a regulation.

The purpose of PCS is to initiate actions that will reduce the nutrient loads to impaired waterbodies, waters that do not meet Delaware's water quality standards. To effectively implement the PCS, there must be extensive effort to educate the citizens of Delaware about the process and impacts of that process on their living, working, and playing. Consequently, there exists a myriad of opportunities to educate both public and private sector on the effects of the PCSs on their daily lives.

TMDLs required for the Delaware Estuary Basin are as follows:

Delaware River (PCBs)	2003
Army Creek, Blackbird, Broadkill, Cedar Creek, Delaware Bay, Dragon Run, Leipsic, Little River, Mispillion, Red Lion, Smyrna and St. Jones	2006

Recommendations - Policy

High Priority - Policy:

Type I

Continue to promote and financially support conservation planning in the Delaware Bay and Estuary Basin and use COMPAS GIS technology to document implementation of best management practices.

Recommend use of septic mapping data in the development of Pollution Control Strategies.

Provide cost-sharing on poultry litter movement from areas of high concentration to areas where it can be utilized to meet crop needs as demonstrated in a comprehensive nutrient management plan.

Offer low interest loans to poultry companies to retrofit feed mills for nutrient reduction in poultry litter.

Advocate cover crop program.

State that P/N nutrient management system is needed.

Finalization and Adoption of updated P Index.

Recommend that the state develop an Animal Feeding Operations strategy (Permits, BMPs, etc.).

Focus nutrient management plans for intensive animal-based agriculture on farm-scale nutrient balance rather than exclusively on field-scale crop response to nutrients applied in animal wastes.

Develop economically viable alternative uses of manure, encourage expedited demonstrations into composting, post composting processing and market potential of composted products.

Support implementation of phytase feed lines by all integrators on the shore by year 2003.

Identify the areas where a significant amount of ground water is being consumed and the Department has little or no water quality data.

Develop and implement pollution control strategies to meet established TMDLs for the Appoquinimink River and Murderkill River.

Develop and implement storm water monitoring plan.

Begin development of TMDLs for remainder of basin.

NPDES Permit synchronization in watersheds/basins.

Review of Septic Regulations considering TMDL/PCS issues.

Implement the Conservation Reserve Enhancement Program (CREP) in the Delaware Bay and Estuary Basin for the following best management practices (BMPs): filter strips, riparian buffers, wildlife habitat restoration, and shallow wildlife areas.

Develop depth to ground water maps for the entire state that highlight areas with an extremely shallow water table.

Review irrigation well water-quality for nutrient loading Incorporate in Management Plans.

Type II

Town zoning codes, conceived in the 1960s, rather than control economic growth instead, prevent it. Traditional Neighborhood Districts, Village Overlays, Transit Oriented Overlays, and updating town comprehensive plans partially or completely, etc. should direct growth to areas where infrastructure already exists.

Intergovernmental coordination zones should be designated in growth areas and areas likely to be annexed to provide the latest and best data to decision-makers.

The Department should encourage the three counties to have a (two or three year) sunset time of rezoned and subdivided land in the non-urban growth areas of this basin. Land in urban growth areas should have longer time span for initiating new construction on rezoned land.

Work with counties and local governments to coordinate septic regulations for greater (average) open space for unsewered areas.

Medium Priority - Policy:

Type I

Targeted ground water monitoring should be incorporated more frequently into BMP implementation projects. If possible, monitoring plans should be developed to discern short-term effects and predict long-term trends to provide a better indication of implementation impact.

Amend the septic regulation to provide for more appropriately located large community septic systems.)

Review analytical site data from all site types for any available nutrient information.

Recommend that the Department deny the placement of new (non-replacement) alternative septic systems outside of investment areas and restrict their placement in investment areas to reduce impacts to wetlands and important habitats.

Assess septic system failure rate for the Delaware Bay and Estuary Basin through remote sensing and verification by grounding survey.

Determine ground water system lag time in various sites throughout the state. This could be very helpful in establishing timetables to see results of Pollution Control Strategies.

Develop a combined strategy to coordinate ground water sampling and share analytical data.

Type II

Encourage update of town plans. The plans would, among other things, prioritize the areas in and around the towns for sewer and water service, annexation procedures, requiring procedures, etc. The plans should include a transportation element, conservation element and economic development element. The Office of State Planning Coordination should grant funds for this.

Corridor preservation for reducing air pollution, runoff, and reducing sewer construction should be supported by the Department along major corridors.

When and where construction is needed, encourage infill to existing developed areas rather than development of “green” spaces. Continue to work with communities to encourage the protection of stream corridors.

Low Priority - Policy:

Type I

Support and develop certification for (required) inspection of septic during property transfer.

Obtain grants to repair, or replace, malfunctioning septic systems in environmentally sensitive areas. Incorporate innovative technologies where appropriate.

Continue to research and demonstrate alternative systems, such as gray-water separation, or the placement of sawdust under tile drainage fields.

Refine regional ground-water flow data with information from all possible sites.

Determine more accurate base flow loading for impacted streams; Compare ground water and surface water data for interactions.

Analyze up-gradient well data from monitored sites to see if there are any regional trends in ground water quality.

Type II

A study should be undertaken to determine the maximum density of an urban growth area must attain before additional undeveloped land is added to an urban growth area. This will have serious implications for infrastructure expansion issues. After a density determination is developed, The State Cabinet Committee on State Planning Issues may establish policy regarding infrastructure expansion when density of an urban area is below the threshold value -perhaps, denying funding for expansions that cannot pay their own way.

3.2 SENSITIVE RESOURCES

The Delaware Bay and Estuary Basin team has identified a number of very diverse resources in the Basin as being "sensitive." These sensitive resources can include living resources such as endangered species or fragile habitat, but also include items as diverse as open space, drinking water supply areas, or even scenic rivers. The Delaware Bay and Estuary Basin contains some of the State's most picturesque areas. However, habitat loss and degradation due to land use practices is impacting many of the species that reside in this basin. Rare and declining species are vulnerable to environmental change and alteration of habitat. Many species exist only in the protected portions of the watershed or rely on certain critical areas for reproduction. This includes both rare and endangered species as well as those considered to be commercially and recreationally important. The locations of some of these critical habitats have not been identified, and may be lost before protective measures can be imposed. Therefore, it is not only important to provide protection to known critical areas, but to those areas that have a high potential as well.

3.2.1 RESOURCE PROTECTION

Some of the state's most valuable natural lands are located in this basin. Many of these are still intact because most growth has occurred in other areas of the state. In a continuing effort to protect these resources the Department and other non-profit organizations regularly evaluate these areas and rank them for acquisition or protection. In most cases, these rankings are based on existing data, and are grouped with those from throughout the state. The Delaware Bay and Estuary Team feels that, because of its relatively undisturbed nature, much of this basin should be evaluated more critically to protect pristine areas before they are lost.

3.2.1.1 Surface Water, Ground Water, and Wetlands

Many of the rivers and streams in the basin are considered to be of exceptional recreational and ecological value. These waterbodies have a great impact on the character of this Basin. In fact, much of the recreation and almost all of the basin's truly natural areas surround these streams. Not only should these streams be protected, but some effort most be made to protect the ground water that provides much of their water. Ground water is the primary source of drinking water in the basin and can account for almost 80 percent of the streamflow. Many factors can help improve both surface and ground water quality, one of which is the preservation of natural wetlands. These wetlands act as buffers and filters for many of the activities and contaminants that would otherwise enter the ground water/ surface water system. In addition, these wetlands provide vital habitat for many of the basin's endangered and threatened species. As one can see this is a complex system that needs to be addressed comprehensively in order to protect many of the basin's sensitive resources.

Recommendations – Surface Water, Ground Water, and Wetlands

High Priority - Surface Water, Ground Water, and Wetlands:

Type I

Promote the acquisition and protection of wetlands and natural heritage sites.

Adopt department-wide comprehensive wetland plan.

Examine current Pond management approaches and develop a more effective, broad-based management approach. Educate pond managers and concerned public to the problems confronting the eutrophication problem in ponds.

Delineation of all source-water protection areas, such as wellhead areas and excellent recharge potential area.

Type II

Adopt statewide wetland mitigation policy. Include the concept of "Land Banking."

Establish wellhead protection ordinances, best management practices, and/or regulations.

Medium Priority - Surface Water, Ground Water, and Wetlands:

Type I

Identify intensive ground water extractive use in areas that may have water availability issues.

The location of all facilities with water allocations should be updated and a coverage created in the Department GIS similar to that created for public supply wells.

Low Priority - Surface Water, Ground Water, and Wetlands:

Type I

Accurately define all sub-cropping aquifer areas to help protect the deeper portions of these aquifers.

Better mapping accuracy for surface water intakes including all irrigational uses.

3.2.1.2 Riparian

Riparian vegetation not only harbors rare species, but also acts as a buffer for adjacent aquatic habitat. Plant roots serve to stabilize banks and impede or filter nutrient laden run-off from entering directly into the surface water. When this habitat is destroyed or altered, there is a loss of plant and animal species and a degradation of water quality. The excess siltation resulting from improper bank management can smother fish egg masses, freshwater mussels, and aquatic vegetation. For some species this habitat is critical to their continued survival.

Current and existing land developments are often constructed without considering the protection of riparian habitat in the planning process. Many shore residents have installed bulkheads or other hard structures to retard bank erosion, a problem that could have been prevented if riparian buffers hadn't been destroyed. As riparian habitats continue to be destroyed and degraded, responsible management is lacking and protection of this habitat type is inadequate.

Recommendations - Riparian

High Priority - Riparian:

Type I

Preservation and restoration of riparian buffer for both natural streams and tax ditches should include new, environmentally friendly, techniques for tax ditch maintenance, inter-agency coordination and public/governmental education.

Develop model zoning ordinance favoring riparian protection.

Promote activities, which eliminate unnaturally high sedimentation and erosion rates, and unnaturally high nutrient inputs. Assess effect of direct stream irrigation on aquatic and riparian systems.

Recommend, whenever practical, the use of non-structural alternatives for erosion control, or a combination of rip-rap with natural vegetation should be emphasized where shoreline erosion is a problem for property owners.

Type II

Work with county and municipal governments to adopt zoning ordinance favoring riparian protection.

Medium Priority - Riparian:

Type I

Encourage stream and pond management that incorporates wide buffers of natural vegetation, including stands of woody species when possible.

3.2.1.3 Living Resources

An undeniable fact within the Delaware Bay and Estuary Basin is that the species composition of the remaining natural areas has permanently changed. The 18th century direct habitat conversion of natural areas to agricultural use has altered a functioning natural landscape into a sprinkling of isolated islands and ribbons of natural areas in a sea of agricultural fields. Add to this the introduction of alien species, pollution, excessive sedimentation, altering of natural waterways, etc., and each natural area is further eroded. Therefore, it is imperative that efforts are made to protect the sensitive resources that still exist within this Basin and also throughout the state.

Recommendations – Living Resources

High Priority - Living Resources:

Type I

The Statewide Wetland Mapping Project data should be compared with the Natural Heritage Inventory to identify areas where additional research and/or protection are needed.

Institute mandatory reporting requirements for commercial American eel harvests to determine the status of the fishery.

Implement American shad restoration and protection projects including: the construction of fish passage facilities, development of a hatchery program, and limiting existing harvests.

Type II

Identify restoration possibilities to increase connectivity between available habitats (include cooperative opportunities with Maryland).

Medium Priority - Living Resources:

Type I

Discourage planting invasive exotic plants in Delaware. Encourage the use of native and non-aggressive exotic plant species. Train management personnel to recognize invasives and to develop management strategies.

Maintain or establish "no wake" zones where needed. The use of non-structural alternatives for erosion control or a combination of rip-rap with natural vegetation should be emphasized where shoreline erosion is a problem for property owners.

Develop a plan to prevent zebra mussels from becoming established in Delaware (educating anglers, boaters etc.).

Type II

Discourage planting invasive exotic plants in Delaware. Encourage the use of native and non-aggressive exotic plant species. Train management personnel to recognize invasives and to develop management strategies.

3.2.1.4 Department Policy and Future Direction

Protecting the sensitive resource in the Delaware Bay and Estuary Basin requires a coordinated effort between numerous parties. In some instances, this coordination occurs smoothly, while in other instances there are many obstacles. The Department needs to evaluate many of its policies with regards to protecting these resources and initiate the appropriate actions within and outside the agency.

Recommendations - Policy
High Priority Policy:

Type I

Establish a methodology for discouraging development in Sensitive Areas.

Type II

The Department should more actively seek agreement with the Office of State Planning on the definition of what is "more than local concern" and therefore trigger reviews under PLUS to protect open space.

Development of lands within State Resource Areas, Natural Heritage Sites, Natural Areas Inventory, and Old Growth Forests should be discouraged.

Critical Areas should be accorded special status and given special attention when a development is proposed on or adjacent to such an area. It is recommended that state and local governments care for these areas. Their actions and decisions should reflect a major commitment toward protecting and conserving these resources.

Implement requirements for buffer zones along streams to protect prehistoric and early historic period archaeological sites.

Establish historic review boards, such as the one in New Castle County, which will result in proactive measures to preserve historic buildings, and efforts to record important features of those that cannot be preserved.

Medium Priority - Policy:

Type I

Develop model open space ordinances.

Type II

Comprehensive plans that are relevant today may become obsolete tomorrow. Most planning and zoning relationships must be reassessed on a continuing basis to guarantee that important land functions continue to operate while the land is used, no matter what the use.

The Department should encourage the development of recreation facilities in and around population centers; encourage the inclusion of usable open space in the subdivision process; and work with local communities throughout the Basin to help them meet the recreation needs of their residents.

Intergovernmental coordination zones should be designated in growth areas and areas likely to be annexed to provide the latest and best data to decision-makers.

Work with county and municipal governments to adopt open space ordinances.

A dedicated effort to improve and enforce County Comprehensive plans must be made in the future to prevent further degradation of natural resources in the state.

When and where construction is needed, encourage infill to existing developed areas rather than development of "green" spaces. Continue to work with communities to encourage the protection of stream corridors.

3.2.2 RESOURCE CHARACTERIZATION

Although there are some highly developed areas in the Delaware Bay and Esturary Basin, some relatively "natural" areas still exist. As population increases and development pressures expand into the basin, many of these sensitive resources may become threatened. Therefore, it is vital to adequately characterize these resources prior to this development pressure so that well-informed decision can be made to implement appropriate and comprehensive protection strategies.

3.2.2.1 Surface Water, Ground Water, and Wetlands

The Delaware Bay and Estuary Basin team defines the sensitive resources in this basin as including not only the traditional endangered species, but also certain natural features and properties. For instance, ground water, which is the Basin's primary source of water for both drinking and irrigation purposes, is deemed sensitive because of the potential for severe degradation from many human activities. Additionally, many rivers, streams, and wetlands, which serve as crucial environmental buffers and habitats, are also appreciated for their aesthetic value and are therefore categorized as sensitive resources.

Recommendations – Surface Water, Ground Water, and Wetlands
High Priority - Surface Water, Ground Water, and Wetlands:

Type I

Complete recharge-potential mapping for the rest of the state.

This mapping shows areas where water and/or contaminants can rapidly enter the ground water.

Develop depth to ground water maps for the entire state that highlight areas with an extremely shallow water table.

Support additional funding for statewide soil survey mapping update.

Medium Priority - Surface Water, Ground Water, and Wetlands:

Type I

Better characterization of metals, pesticides and PCBs in the Delaware Estuary.

Identify intensive ground water extractive use in areas that may have water availability issues.

The location of all facilities with water allocations should be updated and a coverage created in the Department GIS similar to that created for public supply wells.

Low Priority - Surface Water, Ground Water, and Wetlands:

Type I

Accurately define all sub-cropping aquifer areas to help protect the deeper portions of these aquifers.

Better mapping accuracy for surface water intakes including all irrigational uses.

3.2.2.2 Living Resources

In many ways, our living resources reveal more about the state of our environment than any other factor. Our native species are generally the first indicators of change or disruption. They experience first-hand the direct impact of habitat loss, degraded air and water quality, and competition from exotic species. In particular, studies of rare and declining species can play special roles as environmental indicators. These are often the species most sensitive to environmental change and habitat degradation, and hence can bring the first hints of environmental impact. With development pressure increasing it becomes more urgent that these sensitive living resources be accurately characterized throughout the basin.

Recommendations – Living Resources

High Priority - Living Resources:

Type I

A survey of the Delaware Bay and Estuary Basin should be conducted as soon as possible to identify remaining upland forests and to evaluate the quality of these areas using such factors as biodiversity, size, age, and exotic infestation. Appropriate actions should then follow such as natural area designation for qualifying tracts, legal protection, and/or restoration.

A survey of rare habitats should be conducted and summarized. Appropriate actions should be taken to protect these areas, including natural area designation for qualifying tracts, legal protection, and/or restoration.

Critical spawning habitat should be identified through subaqueous mapping and available fish sampling data. Once identified, these areas should be afforded protection from excess siltation, dredging, and water quality degradation.

Once high quality freshwater mussel sites have been identified, they should be afforded protection from habitat degradation.

Work cooperatively with adjacent states to identify the status of the American eel fishery.

Incorporate Delaware Natural Heritage Program databases with other planning databases so that rare species are identified prior to development.

Medium Priority - Living Resources:

Type I

Little information is known about the status of many native fishes (mostly non-game species). More data need to be collected on the presence and population levels of these native species.

Data on spawning locations, spawning success, population structure, and population levels for targeted fisheries need to be collected.

Low Priority - Living Resources:

Type II

A test scale controlled burn should be conducted on fire-dependant plant communities to re-establish the link between fire and the natural diversity and adaptability of the extant species in Delaware's modern forests and marshes.

Acquired the resources necessary to study and quantify the level of ozone-induced crop damage and its associated impacts.

3.3 NON-NUTRIENT CONTAMINANTS

Chemical contamination from "classic" industrial sources and the potential threat of this contamination is not widespread in the Chesapeake Basin. The highest concentration of these sites occurs within, and immediately surrounding, the towns located in each county. Leaking underground storage tanks (LUST) make up a majority of the sites with known contamination. Petroleum hydrocarbons are the chemical contaminants that most often are associated with these LUST sites. Contamination of nearby drinking wells is the most common concern regarding this type of contamination. Besides the LUST sites, there are a number of contaminated sites located throughout the Basin that are managed by other programs within the Department. For instance, the Site Investigation and Restoration Branch oversees the abandoned county landfills, while the Ground Water Discharges Section monitors community septic systems.

Chemical contamination from the use of agricultural pesticides and herbicides has not been fully characterized in the Delaware Bay and Estuary Basin. While chemical contamination is of much less concern than the nutrient contamination in certain areas of the Delaware Bay and Estuary Basin, existing data gaps inhibit the Department's ability to definitively characterize the issue of basin-wide chemical contamination at this time.

3.3.1 RESEARCH AND INVESTIGATION

3.3.1.1 Department Policy and Future Direction

Recommendations - Policy
High Priority - Policy:

Type I

The extent to which metals contamination of the sediment is also a problem in the water column is not well characterized. Historical water column metals data should be compiled and assessed in conjunction with the Preliminary Assessment Report.

Type II

Due to the regional nature of the ozone problem it is essential that we continue to participate with other states, regional and federal agencies on data sharing efforts. Delaware currently works with, and should continue to work with, other states, regional agencies and EPA to communicate ozone data between the various states and agencies.

Medium Priority –Policy:

Type I

Educate the public regarding the proper disposal of motor oil and household chemicals. Continue to support the efforts of the Delaware Solid Waste Authority in its household hazardous waste collection program.

Adequate information currently exists to evaluate status and trends for the criteria pollutants: volatile organic compounds, sulfur dioxide, nitrogen dioxide, carbon monoxide and lead. Data collection and evaluation should continue unchanged.

The periodic ozone precursor emission inventories for VOCs, NO_x, and CO are compiled every three years. The inventories are comprehensive and cover all emission source categories. Emission inventories for SO_2, PM_{10}, TSP, lead and toxics are performed annually but only for large point sources. More comprehensive inventories of these pollutants with the addition of $PM_{2.5}$ are recommended in order to gain additional information on impacts to the Delaware Bay and Estuary and other basins. Impacts of emissions on the Delaware Bay and Estuary and other basins could also be improved by developing methods to enable aerial, mobile, and biogenic emissions to be illustrated in graphical form, such as on a Geographic Information System (GIS) map.

Explore options for acquiring the needed support to produce comprehensive periodic inventories of SO_2, PM_{10}, TSP, lead, and toxics.

Explore options for acquiring the needed support to produce comprehensive periodic inventories of greenhouse gases.

Develop a method to allocate area, mobile and biogenic emissions to geographic basins, and graphically portray those emissions.

The Department should evaluate the extent to which best management practices are being implemented for bulk chemical transfer and storage.

Adequate information currently exists to evaluate the status and trends for $PM_{10.}$ New particulate matter standards for $PM_{2.5}$ have been enacted by EPA and require the development of baseline data from which future reductions may be calculated.

Develop a combined strategy to coordinate ground water sampling and share analytical data.

3.3.2 EDUCATION AND PROTECTION

3.3.2.1 Department Policy and Future Direction

Recommendations - Policy
High Priority - Policy:

Type I

Place EPCRA Tier II facilities on the chemical contaminants map and also populate the Site Index Database with these sites.

Provide technical assistance to towns for the installation of "urban BMPs" such as sand filters and other passive stormwater pollutant reduction devices.

Above ground storage tanks are currently unregulated; develop regulations for operation, spill/overfill protection, leak detection, tank testing requirements and corrosion protection.

Medium Priority – Policy:

Type I

Develop education process for owners of exempt Underground Storage Tanks about proper maintenance and leak detection to avoid become a regulated LUST.

List of Maps